Sorption Processes in Gas Sterilization in the Medical Sector

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Sorption of ethylene oxide during and after gaseous sterilization is influenced by numerous factors. It was found that ethylene oxide desorption not only depends on material to be fumigated but also to a considerable degree on the wrapping material. Although polyethylene, polyamide (nylon), polytetrafluoroethylene (Teflon), silicone, aluminum, and glass beads contained no quantities of ethylene oxide detectable by gas chromatography after 72 h of aeration, residual amounts were definitely determined, even after 76 h of aeration in polypropylene, polystyrene, polyvinylchloride, paper products, and compound products of various plastics and paper mixtures. Desorption was, in all cases, found to be better when a mixture of ethylene oxide and methyl formate was used instead of pure ethylene oxide.

Rapid developments in the plastics industry and progress in the medical sector have made it possible to manufacture valuable and complicated medical equipment from materials with widely differing properties which are, for the most part, thermally unstable. Therefore, these can no longer be sterilized with the conventional means of heat or steam.

Such products include not only those for the purely medical sector (syringes, catheters, blood lancettes, suture material, transfusion and infusion equipment, forceps, and complete operating sets), but also equipment for the entire field of microbiology (petri dishes, pipettes, and diaphragm filters) and items used generally (self-adhesive dressing strips, cotton wool swabs, hygienic products, napkins, and even bottle teats).

The development of this type of product was first made possible by the cold gas sterilization process. A prerequisite to this was gas-permeable but bacteria-impermeable packaging. The previously used paper packaging could not meet these demands with certainty; numerous suitable plastic films and coated papers, however, soon came onto the market (17, 26, 43).

Today, ethylene oxide is the main active substance used in cold sterilization. The bactericidal effect of ethylene oxide was first discovered by Schrader and Bossert in 1936. In 1944, Fraenkel-Conrat investigated the effects of ethylene oxide on proteins (18). Phillips and Kaye carried out fundamental research towards ethylene oxide sterilization in 1949 (37). Numerous other papers were published on the effects of ethylene oxide on bacteria and viruses previously known as resistant or pathogenic (3, 5, 31, 39, 42, 44). It was soon found that the numerous bacterial preparations used had a decisive effect on the success of sterilization (6, 9, 10, 11, 35, 38, 41). In the following period, the main parameters of ethylene oxide fumigation were determined; without a knowledge of these, our present ethylene oxide sterilization would not be practicable (13, 14, 16, 19, 20, 22-25, 28, 29, 32, 36, 40).

Ethylene oxide is used in sterilizers (i) undiluted, (ii) with inert gases such as CO₂, chlorofluorohydrocarbons (freons), or (iii) with formic acid methyl ester. Pure ethylene oxide and air form ignitable gas mixtures in the 3 to 100 vol % range and tend towards autopolymerization (12). Ethylene oxide has a low boiling point (10.7 °C) and therefore very good diffusion properties. Being the simplest form of cyclic ether, it is a strong organic solvent in the liquid phase and is also readily reactive in the gas phase. Ethylene oxide has an alkylating effect (1, 4, 15, A. Jordy, Ph.D. thesis, Mikrobiologisch Institut Johann Wolfgang-Goethe Univ., Frankfurt am Main, 1970, 27, 30) and leads to a greater or lesser effective pH displacement (7, 18). Being a slightly polar gas, sorption is greater with polar than with nonpolar materials. Sorption is to be understood as the bonding of individual molecules or molecular groups, preferably to the
material surface (8). Unlike a chemical reaction, in which molecular structure is broken down and new reaction products are formed, one is dealing here with the continued existence of the unmodified gas molecules, which do not react chemically until a later point in time and when suitable conditions prevail. This ethylene oxide sorption means, in practice, that the treated goods must be stored until no more ethylene oxide is given off and is therefore no longer detectable (2, 21, 33, 34).

The present paper deals with the investigation of sorption processes such as occur under practical sterilization conditions in hospitals, chemical-pharmaceutical plants, and similar operations in which ethylene oxide-carbon dioxide mixtures (EX) or ethylene oxide-methyl formate mixtures (ET) are used (ETOX [EX] and ETOXIAT [ET], Degesch, Frankfurt am Main, Germany). The following report discusses the level of ethylene oxide sorption after treatment with EX and ET, what dependencies on material exist, and how long a product must be aerated to achieve complete desorption of the sorbed ethylene oxide. Also discussed is the extent to which sterilizer packing and various packaging films can influence ethylene oxide sorption.

Fumigation time and ethylene oxide desorption during the first 6 h of aeration are investigated by using rubber as a characteristic example.

The combined effects of ethoxy and methyl groups give ET a broader spectrum than that of EX. It therefore has at least an equal sterilizing effect to ethylene oxide-carbon dioxide mixtures and pure ethylene oxide; ethylene oxide sorption of the treated goods is, however, greatly reduced. Due to the additional buffer effect of the formate component, its overall chemical reaction differs considerably from that of EX.

A further advantage of ET is the safety factor. The typical formic acid odor can be detected earlier than that of ethylene oxide. If one remembers that the odor threshold of ethylene oxide is at 700 ppm but that its maximum allowable concentration value is 50 ppm and that the odor threshold of formic acid, on the other hand, is at 50 ppm, the advantage of using ET becomes even more apparent.

MATERIALS AND METHODS

Materials. The materials investigated represented a selection of the individual products currently used in medicine. They included plastics (processed to tubing, films, and plates), paper and paper-plastic compound materials, metals, and glass. All plastic medical items are packed in gas-permeable welded film and subsequently sterilized. To achieve comparable values, all materials (unless otherwise stated) were packed in 0.1-mm-thick polyethylene film (Suprasan; Kalle A. G., Wiesbaden, Germany) and then welded and sterilized.

Fumigation with EX and ET. The material to be treated (1 g) was packed in polyethylene film (see above) and fumigated at 20 C in a 35-liter chamber using the Degesch (Frankfurt, Germany) vacuum circulatory system (Fig. 1). The chamber was evacuated to 40 torr, and a liquid sterilizing mixture was passed over a vaporator (60 C) and then passed as gas into the chamber. The gas concentration as a mixture of EX or ET in all experiments was 1.250 g/m³ (equivalent mg/liter). This and the fumigation time of 6 h are as used in practice.

On completion of the sterilization period, the chamber was ventilated by evacuating it three times. Groups of 10 samples, 1 g each, of a product were sterilized together, and the ethylene oxide content was determined by gas chromatographic methods after the stated aeration time. Aeration is to be understood as storage of the products in their sealed film packaging in a ventilated room at room temperature.

Gas mixtures used. EX was 90% ethylene oxide and 10% carbon dioxide. ET was 45% ethylene oxide, 45% methyl formate, and 10% carbon dioxide.

Ethylene oxide residue determination after EX and ET treatment. Determinations were carried out with a model 1400 Varian Aerograph gas chromatograph. Acetone was the extraction agent used. The test conditions were as follows. Column data included: dimension, 12 feet by ½ inch (3.657 m by 0.318 cm); material, stainless steel; liquid phase, 20% bb oxidipropionitrile; stationary phase, Chromosorb W 60/80 mesh. Test conditions were: sample quantity, 5 μleters; injection temperature, 100 to 120 C; column temperature, 70 C; detector temperature, 150 C; detector, flame ionization detector; carrier gas, nitrogen; carrier gas flow, 15 ml/min; hydrogen, 25 ml/min; air, 250 ml/min; printer, Varian 20, chart paper feed, 20 inches/h; attenuation, x 1.

Method. One gram of substance was mixed with 10 ml of acetone, mechanically ground and filtered after 48 h. Five microliters of the clear filtrate were taken...
up with a syringe and injected into the column of the
gas chromatograph.

The ethylene oxide peak appeared after 3.8 to 4 min. Its magnitude measured against the calibration curve shows ethylene oxide content in parts per million. The test conditions were checked with control solutions before each series of measurements.

RESULTS

Immediately after fumigation, ethylene oxide sorption shows a scattering up to 10 times with polyethylene, polypropylene, and polyvinyl chloride, a very little scattering with polyamide and polytetrafluoroethylene, and is considerably uniform with paper, cellulose, and compounds of these (Table 1).

Polyethylene sorbed up to 4,000 ppm of ethylene oxide after EX treatment but only up to 2,000 ppm after ET treatment. All results with sorbed ethylene oxide in parts per million are relative to the weight of the investigated material: 1 ppm equals 1 mg/kg.

Twenty-four hours of ventilation lead to a reduction of ethylene oxide content of about 90% in all investigated polyethylene samples, both after EX and ET treatment. In two cases, no ethylene oxide could be detected after 24 h in samples treated with ET.

Throughout the course of longer aeration, the ethylene oxide values approached the zero value asymptotically, in some cases reaching this as early as within 48 h. In one case, however, after EX treatment, the zero value had not been reached even after 96 h.

The results obtained with polypropylene were comparable. Polyvinylchloride with differing plasticisers, on the other hand, was found to have about 10 times greater ethylene oxide sorption capacity than polyethylene and polypropylene. The 2:1 ratio of EX:ET, however, remained unchanged. This far greater ethylene oxide sorption leads also to longer aeration time; it was not always extended until achievement of the zero value.

Venflone, a compound polymer of polyethylene, polypropylene, and polyamide, sorbed ethylene oxide very readily. As the ratio of individual components is not known, one can make no further statements on the individual percentages of ethylene oxide sorption.

The sample of polystyrene was found to have sorbed very much ethylene oxide. Aeration of EX-treated samples lead to insufficient ethylene oxide desorption, whereas the desorption results achieved with the ET-treated samples were good.

Polyamide and polytetrafluoroethylene showed very slight ethylene oxide sorption and, therefore, very rapid desorption.

The ethylene oxide contents found for silicone, silicone and Latex rubber immediately after fumigation, and after various periods of aeration were comparable with those of polyethylene.

Paper, cellulose, and cotton fiber had ethylene oxide contents similar to that of polyethylene immediately after sterilization, but their desorption was insufficient. About 300 ppm of ethylene oxide was still present in the EX-treated samples after 96 h of aeration; the content of the ET-treated samples, on the other hand, was only about 50 ppm.

The ethylene oxide contents of the compound products of paper or cellulose and various plastics were scattered immediately after sterilization. After 96 h of aeration, from very good to insufficient ethylene oxide desorption, depending on the individual components, had occurred, whereby the ET-treated samples always reached the zero value well before the EX-treated samples.

Thin aluminum diaphragms and glass beads sorbed ethylene oxide quantities comparable to those sorbed by polyamide and polytetrafluoroethylene; however, no detectable quantities remained after as little as 24 h of aeration.

Ethylene oxide sorption can also vary, depending on the properties of the packaging films. This question was investigated by comparing the polyethylene film described above with two films used mainly in hospitals. Table 2 shows that ethylene oxide sorption and desorption after EX and ET treatment of rubber (catheter) can differ greatly from the above-mentioned films. With polystyrene, however, the same packaging films lead to very uniform ethylene oxide sorption and desorption in EX treatment (Table 3).

The relation of sorption to sterilizing time and desorption to aeration time have been examined as follows. One-gram rubber samples (catheter) were welded into polyethylene film packs (Suprathen) and sterilized with 1,250 g of EX/m² for 1, 2, 3, 4, and 6 h. The ethylene oxide content of the rubber was determined with a gas chromatograph immediately after fumigation and after 1, 2, 3, 4, 5, and 6 h of aeration (Fig. 2). After 2 h of sterilization the rubber had sorbed more than 50%, and after 4 h the rubber had sorbed almost 100% of the ethylene oxide content determined after 6 h (Fig. 3).

Figures 2 and 4 also show that ethylene oxide desorption is not linear. Desorption from samples sterilized for only 1 h is considerably slower

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APPL. MICROBIOL.
| Products                        | 0 h   | 24 h  | 48 h  | 72 h  | 96 h  |
|--------------------------------|-------|-------|-------|-------|-------|
|                                | EX    | ET    | EX    | ET    | EX    | ET    | EX    | ET    |
| Polyethylene                   | 1,280 | 772   | 138   | 49    | 32    | 0     | 0     | 0     |
|                                | 2,864 | 1,884 | 16    | 0     | 0     | 0     | 0     | 0     |
|                                | 480   | 396   | 66    | 54    | 18    | 0     | 15    | 0     |
|                                | 1,996 | 1,560 | 428   | 218   | 138   | 67    | 60    | 40    |
|                                | 2,080 | 864   | 150   | 50    | 0     | 0     | 0     | 0     |
|                                | 3,840 | 1,980 | 22    | 0     | 0     | 0     | 0     | 0     |
|                                | 2,240 | 652   | 432   | 140   | 186   | 36    | 44    | 0     |
| Polypropylene                  | 696   | 456   | 252   | 186   | 86    | 0     | 58    | 0     |
|                                | 1,312 | 330   | 112   | 74    | 40    | 0     | 34    | 0     |
| Polyvinylchloride              | 4,672 | 3,680 | 2,560 | 1,224 | 728   | 517   | 624   | 432   |
|                                | 7,424 | 4,608 | 816   | 368   | 35    | 18    | 16    | 0     |
|                                | 16,384| 7,466 | 744   | 192   | 0     | 0     | 0     | 0     |
| Plasticized polyvinylchloride  | *17,920* | 11,800 | 2,272 | 1,568 | 656   | 380   | 160   | 20    |
|                                | 8,768 | 4,672 | 2,240 | 2,224 | 942   | 898   | 514   | 448   |
| Polyethylene-polypropylene-    | 1,136 | 780   | 156   | 138   | 78    | 45    | 60    | 40    |
| polyamide                      |       |       |       |       |       |       |       |       |
| Polystyrene                    | *6,464* | 5,312 | 3,328 | 392   | 1,107 | 72    | 860   | 48    |
|                                |       |       |       |       |       |       |       |       |
| Polyamide                      | 226   | 100   | 32    | 18    | 0     | 0     | 0     | 0     |
|                                | 136   | 134   | 32    | 28    | 12    | 0     | 0     | 0     |
|                                | 120   | 82    | 0     | 0     | 0     | 0     | 0     | 0     |
|                                | 296   | 96    | 32    | 18    | 15    | 0     | 0     | 0     |
| Polytetrafluoroethylene        | 352   | 111   | 0     | 0     | 0     | 0     | 0     | 0     |
|                                | 224   | 161   | 0     | 0     | 0     | 0     | 0     | 0     |
| Silicone                       | 3,552 | 1,968 | 280   | 0     | 26    | 0     | 0     | 0     |
| Silicone rubber                | 4,320 | 4,032 | 372   | 84    | 63    | 0     | 0     | 0     |
|                                | 7,168 | 6,496 | 320   | 218   | 105   | 46    | 26    | 11    |
| Latex rubber                   | 5,696 | 4,704 | 944   | 208   | 386   | 78    | 15    | 0     |
| Paper products:                |       |       |       |       |       |       |       |       |
| Defibrillated paper pulp       | 1,504 | 960   | 304   | 88    | 98    | 0     | 94    | 0     |
| Paper                          | *3,040* | 2,160 | 536   | 88    | 66    | 0     | 60    | 56    |
| Corrugated cardboard           | 7,040 | 5,024 | 1,824 | 400   | 668   | 192   | 375   | 106   |
| Cellulose                      | 2,896 | 1,280 | 640   | 160   | 417   | 58    | 263   | 36    |
| Cotton fiber                   | 2,736 | 1,936 | 336   | 52    | 279   | 41    | 216   | 39    |
| Compound products:             |       |       |       |       |       |       |       |       |
| Polymide-silicone rubber       | 1,488 | 792   | 310   | 134   | 150   | 120   | 160   | 64    |
| Cellulose-polyethylene         | 1,632 | 1,280 | 605   | 134   | 181   | 35    | 68    | 0     |
|                                | 1,878 | 1,408 | 580   | 108   | 211   | 0     | 115   | 0     |
| Polylactate resins             | 2,048 | 1,488 | 96    | 36    | 16    | 0     | 13    | 0     |
| Acrylic adhesive compounds     | 3,088 | 2,096 | 278   | 76    | 89    | 18    | 67    | 0     |
| Paper-pp                       | 3,232 | 2,180 | 481   | 108   | 47    | 11    | 23    | 0     |
| Paper-phenolic resins          | 464   | 212   | 166   | 66    | 75    | 39    | 66    | 27    |
| Polystyrene-rubber             | 11,392| 4,096 | 1,200 | 1,056 | 272   | 173   | 91    | 32    |
| Paper blister package          | 3,424 | 3,104 | 712   | 736   | 192   | 145   | 198   | 166   |
| Aluminum                       | 226   | 60    | 0     | 0     | 0     | 0     | 0     | 0     |
| Glass beads                    | 270   | 80    | 0     | 0     | 0     | 0     | 0     | 0     |

* Concentration of gas mixtures was 1,250 g/m³. Sterilization time was 6 h.
Table 2. Ethylene oxide desorption in parts per million after EX and ET treatment of rubber packed in various films

| Film                        | 0 h  | 24 h | 48 h | 72 h |
|-----------------------------|------|------|------|------|
| EX                          |      |      |      |      |
| ET                          |      |      |      |      |
| EX                          |      |      |      |      |
| ET                          |      |      |      |      |
| Polyamide film (0.03 mm)    | 9,792| 7,360| 1,824| 1,368|
| Paper-polyamide (blister package) | 15,232| 11,264| 0    | 0    |
| Polyethylene film (0.1 mm)  | 20,096| 8,576| 552  | 256  |

* Concentration of gas mixtures was 1,250 g/m³. Sterilization time was 6 h.

Table 3. Ethylene oxide desorption in parts per million after EX treatment of polystyrene packed in various films

| Film                        | 0 h  | 24 h | 48 h | 72 h |
|-----------------------------|------|------|------|------|
| EX                          |      |      |      |      |
| ET                          |      |      |      |      |
| EX                          |      |      |      |      |
| ET                          |      |      |      |      |
| Polyamide film (0.03 mm)    | 4,160| 560  | 512  | 458  |
| Paper-polyamide (blister package) | 3,968| 560  | 520  | 348  |
| Polyethylene film (0.1 mm)  | 3,940| 1,120| 936  | 498  |

* Concentration of gas mixture was 1,250 g/m³. Sterilization time was 6 h.

Fig. 2. Desorption of ethylene oxide related to fumigation with 1,250 g of EX/m³ and aeration time. Symbols: +, 1-h treated; ●, 2-h treated; △, 3-h treated; ○, 4-h treated; ▲, 6-h treated.

Fig. 3. Ethylene oxide sorption (%) of rubber catheters related to fumigation time. Gas concentration was 1,250 g/m³.

DISCUSSION

The term, ethylene oxide sorption, includes both physical and chemical sorption. In the present study, only the overall sorption was measured; the characteristics of the above-mentioned types of sorption are briefly described below.

The inner surface of finely dispersed or fine-
sorbed substances can be so large that considerable quantities of other substances can be held by intermolecular forces. This accumulation at the interphase is called sorption; at first, the molecules are deposited in a monomolecular layer, but they then form several layers, one above the other. The sorbed quantity, the sorbend, increases with the inner surface of the sorbing body, the adsorbend. In physical sorption, the sorbend can be separated from the adsorbend once more, completely unchanged. Physical sorption is characterized by low sorption heat and rapid sorption and desorption.

In chemical sorption, the sorbend is bonded to the adsorbend by hydrogen bridges, secondary valencies, electrostatic forces, etc. The type of bond represents a preliminary stage before chemical reaction. After separation, the sorbend is either partially or completely chemically changed. High temperatures which would render physical sorption impossible are essential for chemical sorption. Chemical sorption is slower than physical sorption.

Ethylene oxide, the simplest form of cyclical ether, is slightly polar. It is therefore sorbed in a similar way to water molecules by nonpolar substances and is rapidly desorbed in a manner corresponding to characteristics of physical sorption.

In view of the numerous plastics used today, only a specialist can say whether the one or other plastic sorbs ethylene oxide physically or also chemically. The various additives, copolymers, plasticizers, and manufacturing processes can influence sorption ability.

One of seven polyethylene samples treated with EX shows a very slow desorption and still contained 40 ppm of ethylene oxide even after 96 h of aeration. The polypropylene and three of the polyvinylchloride samples and the polystyrene sample behaved similarly. The scatter of these groups (Table 1) reflects the structural lack of homogeneity which imparts the various properties for the individual applications, for example, flexibility, elasticity, dimensional stability, gas or steam permeability, and thermal stability (33). Paper and cellulose and their compounds also behaved in a way which indicated chemical sorption, i.e., slow desorption.

This paper, however, makes no attempt to differentiate between the two types of sorption, as it is, in practice, only important to know how much ethylene oxide can be sorbed under the most unfavourable circumstances.

The practical importance of the sorption values (Table 1) can be demonstrated, for example, with 1 m$^3$ of sterilized infusion units. One cubic meter can comprise about 1,600 infusion units. The individually packaged unit could, for example, consist of: 12.5 g of polystyrene; 13.0 g of polyvinylchloride; and 4.0 g of paper-polyvinylchloride packaging.

In the following sorption calculations, the maximum values of Table 1 which are marked with an asterisk were deliberately used, as the numerous industrially employed plastics vary greatly in their ethylene oxide sorption behaviors, so that one can readily imagine a compound product which has overall a far less favorable behavior than the individual components shown in Table 1.

Figure 5 shows a clear difference in the sorption of transfusion equipments after EX and ET treatment; this is mainly due to the polyvinylchloride component of the units. Immediately after EX treatment, the cubic meters of infusion units contained 521.43 g of ethylene oxide, and 350.50 g after ET treatment. After 96 h of aeration, 11.98 g of ethylene oxide was still present in the EX-treated samples, whereas the ET-treated samples contained only 0.44 g of sorbed ethylene oxide. After sterilization with
Aeration after gas sterilization is particularly important in the medical sector. It consists of two phases: (i) rapid removal of the gas surplus from the sterilizer and of the gas on the surface of the goods equals ventilation in the sterilizer. A small apparatus usually is ventilated by evacuating three times and rinsing with fresh air until pressure balance is achieved (Fig. 6). This mixing process is, however, not efficient enough for large industrial plants. Here, the vacuum is maintained for 10 to 20 min while rinsing with fresh air, this being followed by ventilation (Fig. 7); (ii) slow gas desorption: this is an equilibrium reaction which can be accelerated, depending on the material and packaging, but not completely eliminated.

Table 2 shows that rubber, for example, sorbs 10 to 20 g of ethylene oxide per kg during a 6-h EX treatment. With an average weight of 10 g, a rubber catheter could therefore have a content of up to 200 mg of ethylene oxide, in spite of triple evacuation and rinsing with fresh air after sterilization. In some hospitals, the sterilizer is only evacuated once.

Ethylene oxide disappears almost completely from the paper-polyamide (blister package) and polyethylene packaging in the course of 24 h. Rubber-packed in polyamide (0.03 mm thick), on the other hand, still contains about 20 mg after 24 h of aeration, and 5 to 7 mg of ethylene oxide, even after 72 h.

As sorption and desorption are equilibrium reactions, the result with the polyamide film demonstrates that this film is not as ethylene

![Fig. 5. Ethylene oxide desorption (% of transfusion equipment related to total sorption after gas sterilization. Concentration of gas mixtures was 1,250 g/m³. Sterilization time was 6 h. Symbols: Δ, EX; ○, ET.](image1)

![Fig. 6. Fumigation cycle of an empty chamber (hospital). 1. Evacuation of the chamber; 2. admission of the gas; 3. fumigation time; 4. aeration.](image2)
oxide permeable as the big and rapid desorption from rubber products necessitates.

In the case of polystyrene (Table 3), the differing types of packaging have no effect on desorption. One reason for this is certainly that polystyrene sorbs considerably less ethylene oxide than polyvinylchloride (Table 1) or rubber and that desorption is considerably slower. It may be that polystyrene only reacts very slowly with ethylene oxide and that therefore the different permeability of the packaging films tested does not appear.

Up to 95% of the sorbed ethylene oxide is desorbed within the first 24 h of normal aeration (Tables 1–3). If, however, solutions are passed through transfusion equipment or if catheters come into contact with mucous membranes whose blood supply is copious, ethylene oxide desorbs considerably more rapidly.

These desorbed ethylene oxide molecules are still highly reactive and can react with the substances of infusion solutions, plasma, sera, etc., but also can react directly via the circulatory system with living cells of the organism.

Implantation experiments have shown that 2 to 8 mg of implanted material per g will suffice to cause slight inflammation of tissue, whereas 9 to 20 mg will cause severe inflammation (2). The albino guppy fish test and the determination of hemolytic products have, however, proved to be considerably more sensitive methods for ethylene oxide toxicology (34).

The relationship between sorption, due to sterilization, and aeration time is shown in Fig. 2. After only 2 h, more than 50% of the final ethylene oxide content has been sorbed; after 4 h, the material has sorbed almost 100% of the quantity determined after 6 h of treatment (Fig. 3). Two-hour treatment periods are being used more and more frequently in hospitals, but 4-h sterilization periods are also quite common.

From Fig. 2 it is also apparent that after 1 h of treatment the gas is desorbed only very slowly; desorption after 2, 4, and 6 h of treatment is more rapid. An aeration period of 6 h is insufficient for all sterilization periods. If one also makes allowances for the fact that these investigations were carried out on a laboratory scale, i.e., aeration was carried out under particularly favorable conditions, one is inclined to suspect that the ethylene oxide values will probably be greater in practice.

The sterilization process also decisively influences ethylene oxide sorption. If, for example, water is sprayed into the sterilizer, the ethylene oxide dissolves in this water film, whereby sorption is further increased and the gas concentration in the sterilizer is reduced.

The course of sterilization in the Degesch circulatory system is shown in Fig. 6–9, first, without goods in the chamber, second, when the chamber is filled with transfusion equipment, and third, when the chamber is filled with highly adsorbent woolen blankets. In the last case, sorption is considerable while the gas is still flowing in; the transfusion equipment, on
the other hand, sorbs the major portion of the gas during the first 45 min.

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