APPENDIX F

CHEMICAL DISINFECTANTS

A number of chemicals are classified as high-level disinfectants and are used alone or in various combinations to disinfect medical instruments and equipment. In addition, some, such as glutaraldehydes and formaldehyde, are also classified for use as chemical sterilants ("cold sterilization") when items are soaked in them for prolonged periods of time (10–24 hours) (see **Chapter 11**).

Two new disinfectants, ortho-phthalaldehyde and peracetic acid, are not covered in this appendix. Experience with both is limited (e.g., peracetic acid is only used in the US in an automated machine for sterilization), and they are expensive. Rather, the intent is to provide performance characteristics on those disinfectants most readily available in countries with limited resources. These include chemicals such as alcohol (ethyl and isopropyl), chlorine and chlorine-releasing compounds, formaldehyde, various glutaraldehydes, and iodines and iodophors.

An exception to this is a novel new disinfectant, called superoxidized water, that has promise for use in developing countries. It is produced by electrolyzing saline (sea water) to create a disinfectant or antiseptic. Because the basic materials (sea water and electricity) are cheap, and the end product (water) is not damaging to the environment, superoxidized water could become an important new disinfectant some day. Because it loses activity with time, usually it is generated at the point of use. Recently, however, when tested under clean conditions, superoxidized water was found to be effective in disinfecting endoscopes within 5 minutes, even when 48 hours old (Selkon, Babb and Morris 1999). Unfortunately, at present the equipment needed to produce the product is expensive.

ALCOHOLS

Ethyl and isopropyl (2-propyl) alcohol (60–90%) are excellent disinfectants that are commonly available and inexpensive. Their rapid killing action and lack of chemical residue makes them ideal for disinfection of many medical items. The activity of both alcohols, however, drops sharply when diluted below 50%, with the optimal concentration range being 60–90% solutions with water (volume/volume).

In many countries, alcohol is available as "industrial methylated spirit" or ethyl alcohol denatured with a small amount of wood (methyl) alcohol (Harpin and Rutter 1982). Because methyl alcohol is the least effective alcohol, it should not be used alone as an antiseptic or disinfectant. Before using, be sure the ethyl alcohol is of adequate strength (60–90%) in locally available "spirit."

Ethyl and isopropyl alcohol are **not** considered to be high-level disinfectants because they do not inactivate bacterial endospores and some viruses. For example, isopropyl alcohol also does not kill hydrophilic viruses (e.g., echovirus, coxsackie virus) (Rutala 1996; Rutala 1993). Alcohols are, however, effective against HBV, HCV and HIV.

Advantages

Rapidly kill all fungi and bacteria including mycobacteria; isopropyl alcohol kills most viruses, including HBV and HIV, and ethyl alcohol kills all viruses; both are tuberculocidal (Rutala 1996).

- Rapid killing action.
- **Not corrosive** to metal.
- Inexpensive in comparison to other disinfectants.
- Useful for soaking rubber or latex items **occasionally**.
- Leave no chemical residue and therefore do not require rinsing.

Disadvantages

- Evaporate rapidly, which makes extended contact times difficult unless the items are immersed.
- Do not penetrate organic material and are easily inactivated.
- Flammable.
- May swell or harden rubber and plastics if used repeatedly or for prolonged periods of time.
- Damage shellac mounting of lenses in endoscopes.

Considerations for Use

- Primarily used as antiseptic and as low- or intermediate-level disinfectant (wiping oral and rectal thermometers and disinfecting external surfaces of equipment—stethoscopes, cryoprobe tips, ultrasound probes, Ambu bags or anatomic models).
- Store in a cool, well-ventilated area because they are flammable.

CHLORINE AND CHLORINE-RELEASING COMPOUNDS

Hypochlorites are the most widely used of the chlorine disinfectants and are available in liquid (sodium hypochlorite) and solid (calcium hypochlorite and sodium dichloroisocyanurate) forms.

Chlorine solutions and compounds are **high-level disinfectants** because they inactivate all bacteria, viruses, fungi, parasites and some spores (Russell, Hugo and Ayliffe 1982). They are fast-acting, very effective against HBV, HCV and HIV/AIDS, inexpensive and readily available. They are extremely useful for decontaminating soiled surgical instruments, gloves and other items as well as large surfaces such as examination tables (Shapshak et al 1993).

When potable (clean) water is available, 0.1% chlorine solution is satisfactory for high-level disinfection. If the chlorine is to be diluted with contaminated (unfiltered) tap water, a higher concentration (0.5%) should be used because much of the chlorine will be inactivated by the microscopic organic matter in the water (WHO 1988). (Instructions for preparing 0.1% and 0.5% chlorine solutions from liquid household bleach [sodium hypochlorite] are listed in **Table 10-1**.) Dilute solutions can also be made from other chlorine-releasing compounds available in powder (calcium hypochlorite or chlorinated lime) or tablet form (sodium dichloroisocyurate) (**Table 10-2**). If stored in closed brown bottles, various concentrations of commercial bleach solutions (1:100 to 1:5) do not lose their efficacy as fast as formerly thought (50% to 97% potency at 30 days), with higher concentrations being more stable (Rutala et al 1998).

Sodium Hypochlorite (Chlorine Bleach)

Advantages

- Usually is the least expensive and most readily available disinfectant.
- Easy to prepare and use.
- Quickly inactivates all viruses including HBV, HCV and HIV, as well as killing tubercle bacillus.
- Very useful for decontaminating soiled surgical instruments, gloves and other items, and large surface areas. (HLD takes 20 minutes, but decontamination can take as little as 60 seconds to kill HIV!)

Disadvantages

- Inactivated by organic matter. (Chloramine-T, an alternative compound that releases chlorine, is not inactivated by organic matter to the same extent as hypochlorites according to WHO 1988.)
- Loses potency on standing if left in **open** container (replace at least daily).
- May corrode metal instruments with prolonged exposure (>20 minutes) to concentrations greater than 0.5%. To minimize corrosion:
  - solutions should not be prepared or kept in metal containers (use plastic containers when possible);[1]
  - exposure time should not exceed 20 minutes; and
  - metal items should be thoroughly rinsed with water and dried after decontamination, or they can be placed in clean water for up to 1 hour before washing.

Note: Depending on the use, HLD versus decontamination, 0.1 % solutions can be made with boiled and filtered (if necessary) water in advance and stored in **closed** dark bottles for at least a month with little loss of potency.

[1] Electrolytic corrosion occurs when two or more dissimilar metals are placed in water or salt solutions, especially if the items are actually touching each other. To avoid this type of corrosion, steel and aluminum instruments should be immersed in separate trays. Also, if metal trays or pans (e.g., stainless steel) are used, a plastic mat or gauze pad should be placed on the bottom of the tray to prevent metal-to-metal contact during soaking. This is especially important when metal instruments are soaked for prolonged periods (12–24 hours) for chemical sterilization.

Considerations for Use

- Decontamination of surgical instruments, gloves and other items before cleaning (0.1%–0.5% depending on the quality of the water).
- HLD of plastic items, such as suction cannulae (0.1% made up in water that has been filtered and then boiled for 20 minutes). (See **Table F-1** for details.)
- Cleaning up blood or other potentially infectious body fluid spills and wiping down large surfaces (0.5%).
- Clean water for drinking or medical use (cleaning instruments) at 0.001%.

Calcium Hypochlorite or Chlorinated Lime

Calcium hypochlorite and chlorinated lime are available in powder form. Recommended dilutions are listed in **Table 10-2**.

- Calcium hypochlorite contains approximately 70% available chlorine.
- Chlorinated lime contains approximately 35% available chlorine.

The availability of prediluted chlorinated lime solutions can be confusing. For example, Eusol® is chlorinated lime and boric acid and contains 0.25% available chlorine. This is sufficient for disinfection of clean equipment, but is half the level recommended by WHO for decontamination of contaminated equipment (WHO 1988).

Advantages

- Both decompose more slowly than sodium hypochlorite, but they still should be protected by storing away from heat and light.

Disadvantages

- Inactivated by organic matter.
- Like all chlorine compounds, may corrode metal with prolonged exposure (>20 minutes) to concentrations greater than 0.5% unless thoroughly rinsed.
- More difficult to prepare dilute solutions due to poor solubility in alkaline water (pH >8) and amount of nondissolvable particulate matter in most products.

Sodium Dichloroisocyanurate

Sodium dichloroisocyanurate (NaDCC) forms hypochlorous acid when dissolved in water. It is available as powder or tablets. NaDCC powder has 60% available chlorine; NaDCC tablets contain 1.5 g available chlorine per tablet. (See **Table 10-2** for how to make recommended dilutions.)

Advantages

- NaDCC does not decompose as quickly as sodium or calcium hypochlorite.
- Tablets are easy to use for measuring.

Disadvantages

- More expensive than sodium or calcium hypchlorite.
- Like all chlorine compounds, they may corrode metal with prolonged exposure (>20 minutes) to concentrations greater than 0.5% unless thoroughly rinsed.

FORMALDEHYDE

Formaldehyde in both liquid and gaseous forms can be used as a chemical sterilant, as well as a high-level disinfectant (Taylor, Barbeito and Gremillion 1969; Tulis 1973). Its uses are limited by its irritating fumes and pungent odor. Formaldehyde is classified as a potential carcinogen; therefore, care must be taken to protect staff when preparing and using formaldehyde solutions (see **Disadvantages**, below).

A commercially available solution of formaldehyde (formalin), which contains 35–40% formaldehyde by weight, should be diluted with boiled water (1:5) to a final solution containing about 8% formaldehyde.

Details for preparing and using formaldehyde (formalin) solutions are provided in **Table F-1**.

Advantages

- Not readily inactivated by organic materials.
- Can be used for up to 14 days.
- Can safely be used on surgical endoscopes (laparoscopes) because 8% formaldehyde will not corrode metal or damage lensed instruments, plastics or rubber.

Disadvantages

- Causes skin irritation.
- Irritates the skin, eyes and respiratory tract, even at low concentrations.
- For sterilization, 24-hour soaking in 8% formaldehyde solution kills all microorganisms, including bacterial endospores.
- Produces a dangerous gas (bis-chloromethyl-ether) when mixed with chlorine.

Considerations for Use

- Because of the potential carcinogenicity in humans and noxious fumes, liquid or gaseous formaldehyde should not be used for HLD or sterilization if other high-level disinfectants are readily available. In many developing countries, however, formaldehyde continues to be used because both liquid and solid forms (paraformaldehyde) are extremely inexpensive, readily available and have been used in hospitals and clinics for many years. Switching over to less toxic compounds, such as glutaraldehydes or other newer high-level disinfectants, is strongly recommended but difficult to implement because of the high cost of alternatives.
- Replace solution sooner than 14 days if cloudy.
- Handle with care. Gloves should be worn to avoid skin contact, eyes should be protected from splashes and exposure time should be limited.
- Use only in a well-ventilated area. (OSHA exposure standard for formaldehyde limits the 8-hour time-weighted average exposure to a concentration of 0.75 ppm [OSHA 1991].)
- **Thoroughly** rinse equipment with sterile water or boiled and filtered (if necessary) water at least **three times** after soaking.

GLUTARALDEHYDES

Glutaraldehydes are widely used for chemical sterilization and HLD of medical instruments. Aqueous solutions are acidic (pH < 7) and only when made alkaline are they activated. There are many types of glutaraldehydes available worldwide. The most commonly used is an alkaline-stabilized 2% glutaraldehyde available commercially as Cidex® or Cidex 7®. These chemicals, which are derivatives of formaldehyde, also are irritating and the fumes very unpleasant; therefore, they should be used only in well-ventilated rooms.

Because the stability and activity of glutaraldehydes vary considerably depending on how they are prepared and stored, the manufacturers' directions must be followed closely. In general, for effective HLD, instruments and other items should be soaked for 20 minutes, while for sterilization, instruments should be soaked for 10 hours (see **Table F-1** for additional information).

Remember: Do not dilute unless specified in the manufacturer's instructions.

Until 1991, glutaraldehyde products were available in alkaline, neutral or acid forms. Since then, reports have documented that neutral or alkaline glutaraldehydes have superior killing power and anticorrosive properties when compared with acid glutaraldehyde (Rutala 1996). As a consequence, beginning in 1991 acidic glutaraldehyde products were gradually removed from the market. Recently, however, a new diluted product containing 0.95% glutaraldehyde with 1.64% phenol/phenate has been cleared by the USFDA for HLD. The antimicrobial efficacy of this product, however, needs to be

independently validated before it can be recommended. Also, like all glutaraldehydes, it is expensive.

Further details for preparing and using glutaraldehydes are provided in **Table F-1**.

Advantages

- Not readily inactivated by organic materials.
- Generally can be used for up to 14–28 days (see **Table F-1** for details).
- Can safely be used on surgical endoscopes (laparoscopes) because they will not corrode metal or damage lensed instruments (endoscopes), plastics or rubber.

Disadvantages

- Can cause skin irritation or dermatitis with chronic exposure.
- Vapors are irritating to mucous membranes (eye, nose and mouth) and respiratory tract.
- Work best at room temperature (20–25°C or 68–77°F).
- Expensive.

Considerations for Use

- At present, best disinfectant for HLD and cold sterilization of medical instruments that are heat-sensitive.
- Replace solution sooner than 14 days if cloudy.
- Wear gloves and protective eyewear in case of splashes and sprays.
- Use only in a well-ventilated area.
- **Thoroughly** rinse equipment with sterile water or boiled and filtered (if necessary) water at least **three times** after soaking.
- Soaking for longer than 20–30 minutes may be required to kill mycobacterium in cold climates.

Note: Some brands can be used for longer periods of time, up to 28 days. Check the manufacturer's instructions (Rutala 1996).

IODINES AND IODOPHOR SOLUTIONS

Iodine solutions (1–3% aqueous or tincture) and iodophors (iodine complexed with an organic material) have been used primarily as antiseptics for many years.

Note: Iodophors manufactured for use as antiseptics are **not** effective for disinfecting inorganic objects and surfaces. Antiseptics have significantly less iodine (Rutala 1996). Be sure to check the label.

Aqueous iodine solutions can be easily made up, and they as well as iodophors are readily available in most countries. Povidone-iodine (PVI) is a commonly available iodophor, usually sold as a 7.5–10% solution (1% iodine). (For instructions on preparing an iodophor solution, see **Table F-1**.)

Iodophors are **not** high-level disinfectants because conclusive evidence is lacking that they are effective against bacterial endospores and some fungi. Also, pseudomonas species, a group of gram-negative bacteria, have been

known to multiply in iodophors (Favero 1985; Rutala 1993). They are generally nontoxic and nonirritating to skin and mucous membranes.

Advantages

- Do not cause deterioration or softening of plastic items if items are kept dry between soakings.
- Diluted solutions of iodine and iodophors are nontoxic and nonirritating (unless the person is allergic to iodine).
- Can be used for disinfection of blood culture bottles and medical equipment such as thermometers.

Disadvantages

- Iodine is an **oxidizing agent** (causes rust) and should be used only for high-quality stainless steel equipment or plastic materials.
- Like alcohol and chlorine, iodine and iodophors are inactivated by organic materials; therefore, only previously cleaned instruments should be placed in iodine or iodophor solutions.
- **Thoroughly** rinse equipment with sterile water or boiled and filtered (if necessary) water at least **three times** after soaking.
- Allergic reactions can occur to staff handling iodine solutions and iodophors.

Note: Iodophors must be **properly diluted** to be effective. Correctly diluted iodophors have more active killing power than full-strength iodophors due to the decreased availability of "free" iodine in the full-strength products.

Considerations for Use

- Primarily used as antiseptic for skin and mucous membranes (aqueous preparations only)
- 3% aqueous solutions can be used for decontamination, but must be made fresh daily

Table F-1. Preparing and Using Chemical Disinfectants

CHEMICALS FOR STERILIZATION OR HIGH-LEVEL DISINFECTION

Disinfectant (common solution or brand)	Effective Concentration	How to Dilute	Skin Irritant	Eye Irritant	Respiratory Irritant	Corrosive	Leaves Residue	Time Needed for HLD	Time Needed for Sterilization	Activated Shelf Life[a]
Chlorine	0.1%	Dilution procedures vary[b]	Yes (with prolonged contact)	Yes	Yes	Yes[c]	Yes	20 minutes	Do not use	Change every 14 days, sooner if cloudy.
Formaldehyde (35–40%)	8%	1 part 35–40% solution to 4 parts boiled water	Yes	Yes	Yes	No	Yes	20 minutes	24 hours	Change every 14 days, sooner if cloudy.
Glutaraldehyde (Cidex®)	Varies (2–4%)	Add activator	Yes	Yes (vapors)	Yes	No	Yes	20 minutes at 25°C[d]	10 hours for Cidex	Change every 14–28 days; sooner if cloudy.
Hydrogen Peroxide (30%)	6%	1 part 30% solution to 4 parts boiled water	Yes	Yes	No	Yes	No	20 minutes	Do not use	Change daily; sooner if cloudy.
CHEMICALS FOR DISINFECTION (alcohols and iodophors are not high-level disinfectants)										
Alcohol (ethyl or isopropyl)	60–90%	Use full strength	Yes (can dry skin)	Yes	No	No	No	Do not use	Do not use	If container (bottle) kept closed, use until empty.
Iodophors (10% povidone-iodine) (PVI)	Approximately 2.5%	1 part 10% PVI to 3 parts water	No	Yes	No	Yes	Yes	Do not use	Do not use	If container (bottle) kept closed, use until empty.

[a] All chemical disinfectants are heat- and light-sensitive and should be stored away from direct sunlight and in a cool place (< 40°C).
[b] See **Tables 10-1 and 10-2** for instructions on preparing chlorine solutions.
[c] Corrosive with prolonged (> 20 minutes) contact at concentrations > 0.5% if not rinsed immediately with boiled water.
[d] Different commercial preparations of Cidex and other glutaraldehydes are effective at lower temperatures (20°C) and for longer activated shelf life. **Always** check manufacturers' instructions.

Adapted from: Rutala 1996.

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