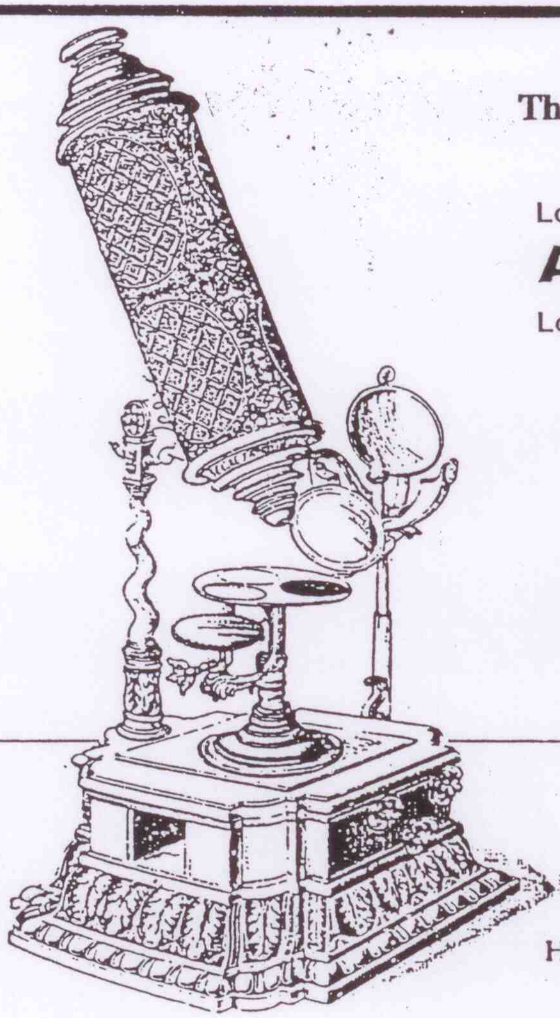
Microbial Pest Control



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Hertel's microscope (1716)

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COOPERATIVE EXTENSION SERVICE/THE UNIVERSITY OF GEORGIA COLLEGE OF AGRICULTURE/ATHENS

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PREFACE

Federal and state regulations establish general and categorical standards that must be met before you can legally use certain pesticides. This guide contains basic information to help you meet both the general and categorical standards for applicators who need to be certified to use certain antimicrobial agents.

Microorganisms, also known as microbes or "germs," are living cells so small that most can be seen only with a microscope. Algae, fungi, bacteria, and viruses are all microbes. Any substance or mixture of substances that acts against microbes is an antimicrobial agent.

This manual deals with the following types of antimicrobial agents to be used on inanimate objects or fluids to control microorganisms:

- Disinfectants
- Sanitizers
- Bactericides and bacteriostats
- Virucides
- Sterilants
- Algaecides
- Fungicides and fungistats
- Antifoulants
- Preservatives
- Slimicides
- Mildewcides

Antimicrobial agents used to protect and preserve wood products from microorganisms are not included.

For the purposes of this manual, the term "microorganism" will refer only to the bacteria, fungi, algae and viruses.

The final chapter provides definitions of many specialized terms used to describe antimicrobial pesticides and how they work.

Note: To be certified in the category of anti-microbials, you must pass a written exam based on all chapters of this manual with the exception of the chapter on "Equipment, Application Methods, and Chemicals." You are required to study only the section in this chapter applying to your area of work.

Microbial Pest Control

MICROORGANISMS

Microorganisms are found nearly everywhere—in water, air, dust, and soil; in most nonprocessed foods; and in all decaying matter. Man and animals have microorganisms on their skin and hair, in their intestinal tracts and feces and in the fluid discharges of their bodies.

Most microbes are harmless under normal conditions. In fact, they may perform useful functions. For example, most plant and animal life could not exist without some kinds of microbes; other kinds of microbes are used in many industrial processes.

A major function of microorganisms in nature is their role in the decay process. What would happen if there were no microbial activity to break down such things as animal carcasses, vegetation, and tree stumps? Urban life depends on bacteria for sewage treatment. Microorganisms are used in the fermentation industries to produce such things as organic acids, sauerkraut, alcoholic drinks, bread and cheese. Some are the source of antibiotics used in medicine.

Some microorganisms, however, are harmful. They cause many kinds of diseases. Microorganisms can also damage commercial products. For example, they can cause undesirable changes in such materials as adhesives and plastics.

Bacteria

Bacteria are microscopic, one-celled organisms that lack the green pigment, chlorophyll.

Four hundred million (400,000,000) of these cells equal the same size as one grain of granulated sugar. When bacteria are magnified 1,000 times, they look no bigger than a dot on this page.

Bacterial cells reproduce by dividing in half (fission) to become two identical cells. Under ideal conditions, some bacteria reproduce as often as once every 15 to 30 minutes. One bacterium could become 70 billion bacteria in only 12 hours.

Bacteria are divided into two major groups based on a staining technique called a Gram stain. Those that stain violet are called Gram positive; examples are the bacterium that causes tetanus *(Clostridium tetani)* and the bacterium that causes acne infections *(Staphylococcus aureus)*. Those that do not stain violet (but take a counter stain of another color) are called Gram negative; examples are the bacterium that causes typhoid *(Salmonella typhosa)*, and a bacterium that can break down or contaminate a number of living and nonliving things *(Pseudomonas aeruginosa)*.

In addition to their staining characteristics, bacteria can also be grouped on the basis of their form. All of the thousands of species of bacteria have one of three general forms: spherical (round), rod-shaped, or spiral (see Figure 1).

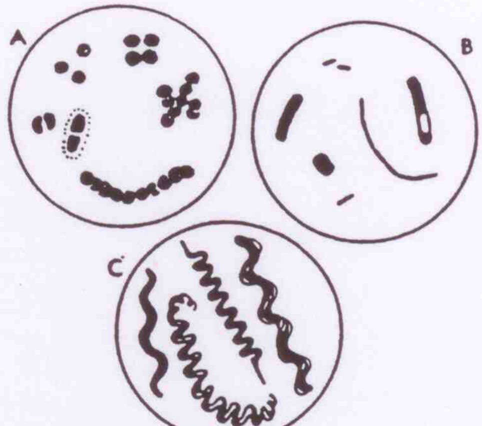

Figure 1. Shapes of bacteria. A. spherical; B. rod-shaped; C. spiral.

Spherical cells are cocci (singular, coccus). Many bacteria of this shape are identified by the patterns in which the sperical cells are arranged.

Some of the rod-shaped bacteria form a spore within the cell. The spore may later develop into a new cell. Bacterial spore formation is not a type of reproduction because there is no increase in the number of organisms (see Figure 2).

Spores are extremely resistant to heat, chemicals and drying, but the cells that form spores are no more resistant to these adverse conditions than are other bacterial cells. While some spores may withstand boiling many days, vegetative cells (stage of active growth) may be killed within a few minutes.

Some types of bacteria do not produce spores. Their life cycle includes only reproduction by fission.

The third principal bacterial form is spiral or screw-shaped. This group includes the spirochetes.

Some bacteria are enclosed in a capsule which may protect them from antimicrobial agents.

Some bacteria produce poisonous substances (toxins) that can cause diseases, such as lockjaw or food poisoning, in man. Other bacteria produce enzymes that can:

- Dissolve or destroy living cells or industrial goods.
- Foul surfaces that we contact daily.
- Contaminate equipment and food products.

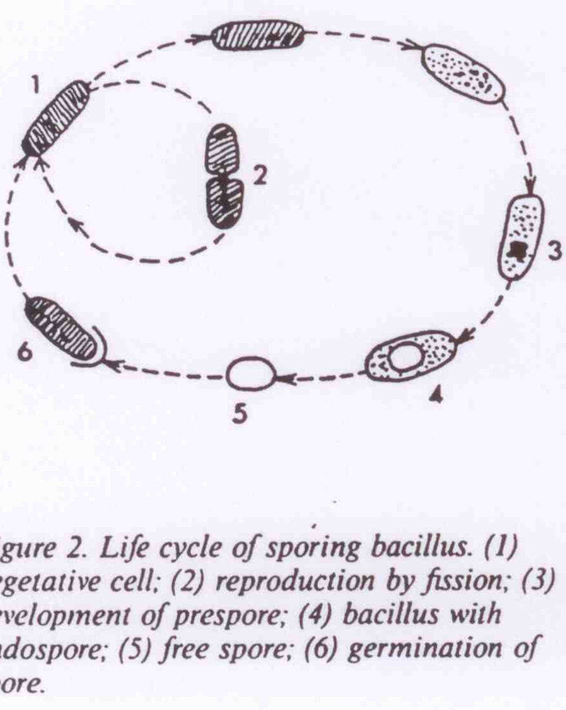

Figure 2. Life cycle of sporing bacillus. (1) Vegetative cell; (2) reproduction by fission; (3) development of prespore; (4) bacillus with endospore; (5) free spore; (6) germination of spore.

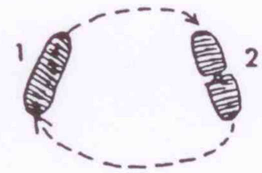

Figure 3. Life cycle of a non-sporing bacteria. (1) Vegetative cell; (2) reproduction by fission.

Fungi

Fungi are a large group of nongreen plants that live by feeding on either living or dead organisms. They cannot make their own food because they lack the green plant pigment, chlorophyll. Some fungi, such as yeasts, occur as single cells that you would need a microscope to see. Others, such as mushrooms, are quite large. Over 100,000 species of fungi have been identified. Fungi and bacteria are often found together in nature.

Many fungi are useful. They are necessary, for example, in the making of bread, cheese, wine and beer. Some, such as mushrooms, are used as food. Other types are troublesome because they cause decay and mildew. Fungi grow on a wide variety of natural and industrial products.

Some fungi cause diseases in humans. Coccidiosis and histoplasomosis are fungal diseases caused by inhaled spores that infect the lungs and other internal organs. Ringworm is an infection of the skin and nails caused by fungi.

Fungi reproduce in several different ways. Some reproduce from cellular fragments of the fungal organism. Others produce spores which function like seeds of higher plants. Spores of fungi are not as resistant to chemicals, heat, or drying as spores of bacteria.

Algae

Algae are similar to the fungi, but contain chlorophyll and other pigments. Algae range in size from one-celled, microscopic organisms to 200-foot-long (61-meter) seaweeds. They live in fresh or salt water, and on land.

Algae are classified by their color: blue-green, brown, red and green. They may appear on water as patches of green scum called "pond scum." On soil or tree trunks they appear green or blue. At the seashore, green, red and brown seaweeds can be seen.

Algae are the source of food that makes aquatic life possible. Some types are used as human food and others have industrial uses.

In some cases, however, algae can be quite troublesome. For example, they may:

- Give drinking water a disagreeable taste or odor.
- Cause bathers to itch.
- Poison fish.
- Clog water-filtering systems and water cooling towers.
- Interfere with pulp-mill operations.
- Foul underwater structures.

When water temperatures and nutrients reach a favorable level, certain algae multiply very rapidly. Some cause "algal bloom" or pond scum, which may seriously affect the other forms of water life and the water quality. Large masses of algae in shallow pond and lake water can deplete the oxygen and cause fish kills.

Unlike the bacteria, viruses, and fungi, algae have little direct medical importance to man.

Slimes

Slimes are combinations of fungi, algae, bacteria and other organisms. Slimes can be troublesome in any water system, including industrial water-cooling towers and in paper mill wet-end systems.

Viruses

Viruses are parasites that live and reproduce only inside the living cells of their selected host. Viruses are about 1,000 times smaller than bacteria, and are seen only with the aid of an electron microscope.

A virus enters a living plant or animal cell and reproduces itself within that cell. It usually destroys the cell, however, and must enter another cell to survive. A virus has no means of movement. It depends on air, water, insects, humans, or other animals, to carry it from one host to another. Some viruses survive away from the host for many hours or days when in organic material such as scabs, blood, and body wastes.

Some of the diseases of man caused by viruses are smallpox, rabies, yellow fever, influenza, measles, mumps, polio, and hepatitus. Canine distemper and foot-and-mouth disease are two viral diseases that affect animals. Plant diseases caused by viruses are major agricultural problems. Plants affected include vegetables, fruits, sugarcane, and tobacco.

CONTROL OF MICROORGANISMS

Many microorganisms are helpful, but some must be controlled. To insure that patients do not contact infectious material, hospitals must:

- Sterilize or disinfect certain items for patient use.
- Keep floors and other surfaces free from harmful microorganisms.

In industry, control is necessary to protect raw materials, manufactured products, manufacturing processes and systems, equipment, surfaces and areas from contamination, defacement, deterioration, fouling and spoilage.

Principles of Control

Microorganisms are all about us. We too often think that chemicals are our only or best method of control, and forget that other methods can be used. The major ways to control microorganisms are to:

- Prevent their entry.
- Keep materials and surfaces clean so that microbes will have nothing to feed on.
- Keep materials and surfaces dry so that microbes will not have enough moisture to multiply.
- Keep the temperature low enough or high enough so that the microbes either cannot grow or are killed.
- Use chemical agents.

A combination of methods is basic to most microbial pest control. The challenge lies in our ability to use the best method or combination of methods to achieve the desired control level.

Methods of Control

Nonchemical Control

Prevention of entry—Walls and other physical barriers can be used to prevent microbes from entering certain areas. You may need special steps to reduce the number of organisms being brought into a critical area by people, equipment, and supplies. Some of the methods used are:

- Requiring employees to wear clothing cleaned by the institution (not street clothes).

- Requiring employees to change shoes or put on shoe covers when entering critical areas.
- Requiring employees to wear hair covers and face masks.
- Keeping equipment and supplies clean.

Air currents often carry microorganisms into areas where they are unwanted. A combination of recirculating filtered air and positive pressure reduce airborne microorganisms in "clean" areas.

Scrubbing—Scrubbing is usually done with water and some chemical agent, such as soap or detergent. Scrubbing removes dirt and other matter that contain microbes.

By adding an antimicrobial pesticide to certain detergents, both cleaning and antimicrobial action can be accomplished. These products are called "detergent disinfectants" or "germicidal detergents".

Air filtration—Microorganisms, particles (such as dandruff or dirt), or liquid droplets dispersed in a gas are called aerosols. Two types of filter materials are used to remove these aerosols from the air. The fibrous mat type is the most common when large volumes of the air must be handled (such as in industries and hospitals). Membrane filters are becoming more important in critical applications.

Fluid filtration—Filtration is the only way to make some biological and pharmaceutical fluids sterile and particle-free. This method involves passing a mixture of fluids and solids through a porous medium. It traps any microorganisms larger than the pore size of its surface. Mat and membrane filters are most often used, sometimes in combination.

Boiling—Boiling can be used to disinfect objects. It kills fungi, most viruses, and most vegetative forms of bacteria in a few minutes. Bacterial spores may resist boiling for many days.

Steam—Applying saturated steam under pressure (autoclaving) is most widely done to sterilize materials and articles; generally, it is considered most reliable. Many combinations of time and temperature are considered satisfactory for steam sterilization. For example, autoclaving for a least 15 minutes at a minimum temperature of 121° C (249.8° F) is an accepted minimal standard. Time and temperature may vary, depending on the size of the load and type of material.

The saturated steam must be at the proper temperature and reach all parts of the sterilizer load. Be sure air is removed from the sterilizer chamber before sterilization so that the steam will penetrate the load.

Dry heat—The use of dry heat to control microorganisms is one of the oldest known methods. Gas or electric ovens are generally used. The ovens usually have a thermostat, and some may have fans to circulate the hot air.

Any material that withstands the temperature of dry heat sterilization can be treated satisfactorily this way. Use the correct combination of exposure time and temperature. Exposure to a temperature of 160° C (320° F) for two hours or 170° C (338 ° F) for one hour generally achieves sterilization.

Incineration is a form of dry heat sterilization. Incinerators work by completely burning microorganisms. An example is direct flaming of instruments, such as forceps.

Radiation—Artificially produced ultraviolet (UV) radiation is used in many ways for microbial control. UV radiation kills vegetative cell bacteria, but usually not fungal and bacterial spores. UV radiation does not penetrate well; therefore, it may not kill microorganisms which are either in clumps or covered by dust and other debris. Because of this fact, UV radiation has limited usefulness. Gamma and x-rays are also biocidal, but such application is quite specific and is not widely useful today for economic reasons.

Chemical Control

Nonchemical methods do not always give adequate control of microorganisms. Therefore, antimicrobial pesticides are often necessary. Use them:

- Where they are needed.
- Where they can be used safely.

Select and use them so they work with other methods whenever possible. Be careful not to harm yourself or the environment. Remember, chemicals often will not give adequate control unless they are used in combination with other methods.

Choosing the right antimicrobial agent is not easy. In 1974, over 8,000 brands of disinfectants, sanitizers, preservatives, and sterilants were registered with EPA for sale in the United States.

Chemical Groups

The most common antimicrobial agents are in one of the following chemical groups. You may not be able to tell which chemical group an antimicrobial formulation belongs to unless you are able to interpret the chemical name(s) listed on the label as "active ingredients." Examples of a few chemical names are given for some of these groups.

Halogens

The halogens are chlorine, bromine, iodine, and fluorine. Some are used in antimicrobial agents. They are powerful oxidizing agents and must be applied only to materials able to withstand their strong chemical activity.

Chlorine—Chlorine gas, household bleach (calcium or sodium hypochlorite), or chemicals that release chlorine (sodium dichloro-s-trazinetrione) are common antimicrobial agents. They are used on surfaces or objects not damaged by the oxidizing and bleaching activity. Chlorine is used to treat drinking water, swimming pools, water-cooling towers, and dairy and food processing equipment. These chemicals are also used in laundry processing and paper manufacturing.

Chlorine dioxide—This product is used to a limited extent in water treatment to eliminate odor and taste problems. It is applied extensively in the pulp and paper industry for bleaching purposes.

Iodine—Both iodine itself and chemical combinations (polyethoxy polypropoxy polyethoxy ethanol - iodine complex) that release iodine are used to treat surfaces or objects not damaged by staining or by the strong chemical action. Products used for surface treatment are usually special iodine preparations that minimize staining.

Heavy Metals

Certain metal salts have strong antimicrobial activity even when diluted. Some (mercury, arsenic) have limited usefulness because they are highly toxic to man and other living forms. Modern day usage of these products is strictly controlled and for the most part, entirely banned.

Mercury—Salts of this element are used to treat inanimate surfaces, but use is limited because of the toxic residues they leave. Mercurial formulations are used as preservatives for leather (phenylmercuric acetate), paper, pulp, paints (phenylmercuric oleate), and adhesives (phenylmercuric hydroxide).

Silver—Silver compounds have been used for many years as antiseptics and disinfectants. Colloidal silver is sometimes used in water filters.

Copper—Soluble salts of copper are antimicrobial agents. Their use is limited because they break down so quickly in the environment. Copper sulfate is used to control algae in swimming pools and other waters. More stable copper compounds control fungi and mildew in paint formulations (copper-8-quinolinolate).

Zinc—Zinc oxide is widely used as a mold inhibitor in paint.

Arsenic—Organic arsenicals are used to preserve plastics (oxybisphenoxarsine).

Tin—Organic tin compounds are used as preservatives for paint films (bistributyltin oxide), plastics (tributyltin linoleate), and textiles (tributyltin acetate), and as fungal control agents (tributyltin oxide) exhibiting a synergistic effect with quaternary ammonium compounds to provide a good overall microbiocide in industrial water-cooling systems.

Phenolic Derivatives

Many synthetic chemicals related to phenol (carbolic acid) are in formulations used for disinfecting and sanitizing (orthobenzyl para-chlorophenol, ortho-phenylphenol). These formulations are for treating equipment and surfaces such as floors and walls. They also are used as preservatives for textiles, leather, and paints. Some are corrosive and must be handled with care. Chlorinated phenols identified here are also formulated with other antimicrobial chemicals for use as slimicides in the manufacture of paper and in water-cooling towers.

Quaternary Ammonium Compounds

These compounds, widely known as "quats," are related to detergents. They have weak to strong antimicrobial activity against selected groups of microorganisms, and they penetrate well. They are used to disinfect room surfaces, laundry, and other materials. Examples of such quats are as follows:

alkyl (60%C_{14}, 30%C_{16}, 5%C_{12}, 5%C_{18}) dimethyl ethylbenzyl ammonium chloride and methyldodecylbenzyltrimethyl ammonium chloride.

Some formulations are used as algaecides in swimming pools and in industrial cooling water systems.

Organo-Sulfur Compounds

Although some of these products exhibit a noticeable "sewer gas" odor, compounds such as the sodium and potassium salts of dimethyldithiocarbamate find wide application as bacterial and fungal control agents in recirculating cooling water systems.

One of the most widely applied products of this class, methylene bis-thiocyanate, is an effective algal and bacterial control agent even in the presence of organic matter and oils in recirculating cooling water systems.

Alcohols

Ethyl and isopropyl alcohols—Ethyl and isopropyl alcohols in concentrations of 60 to 95 percent have bactericidal action. Methyl alcohol is not widely used for disinfection because it is toxic and is a weak bactericide. Alcohol preparations are used on equipment and other materials not damaged by their solvent action. Alcohols are flammable and must be handled with care.

Glycols—Formulations of single or mixed glycols (such as triethylene glycol) can be applied as fine aerosols or mists. They are used to temporarily reduce bacterial numbers in the air in enclosed spaces.

Aldehydes

Formaldehyde—Use gaseous formaldehyde as a sporicide and disinfectant in enclosed areas (such as rooms or small chambers), but it penetrates poorly. Maintain high humidity (70 percent or more) for effective results.

Glutaraldehyde—Hospitals and dental offices use glutaraldehyde formulations to disinfect and sterilize medical equipment.

Oxiranes

Ethylene oxide—Ethylene oxide (EO) is an effective and widely-used gas to sterilize medical supplies that may otherwise be damaged by heat. Some ethylene oxide products are flammable and explosive. Read the label. EO is also available as a nonflammable mixture with CO_2 or with Freon; neither of these inert diluents affect the microbiocidal activity of EO. Use EO in equipment with adequate control measures.

Types of Formulations

In an antimicrobial product, chemicals that are effective against microorganisms are called active ingredients. Each of these will be named on the container label.

Few products contain only active ingredients. They also contain other chemicals called inert ingredients. The latter chemicals are added to make the product more stable; safer and easier to handle, measure, and apply; or to make it effective for other uses such as cleaning.

The mixture of active and inert ingredients is called the formulation. Some formulations are ready to use just as you purchase them. Other formulations must be diluted with water. The label directions tell you how to use each formulation. Many antimicrobial agents are used for more than one purpose. Each use may require a different concentration. Be sure the solution you prepare is in the correct concentration for the job you need to do. Follow the label directions carefully.

Here are the most common types of formulations:

Concentrated Liquids

Water-based concentrates are very common. The formulation often contains more than one active ingredient, as well as several inert ingredients. A typical concentrated liquid is prepared for use by adding the recommended volume of the concentrate to the stated amount of water to form a diluted solution. Read the label to determine the correct dilution and whether to add water to the product, or the product to water.

For water treatment uses (slimicides for paper mills, algaecides for cooling towers, disinfectants for drinking water) a measured amount of concentrate is normally added directly to the system.

Soluble Solids

Dry formulations, such as powders and granules, are also quite common. Some contain 100 percent active ingredient, and some are mixtures. In most cases, these formulations must be dissolved before using. The proper solvent is specified on the label.

For water treatment, the directions may say either to add the dry product directly at a point in the system where there is good mixing, or to prepare a liquid concentrate before adding it to the system.

Granules, pellets, or briquets for water treatment release the active ingredient slowly over a long period of time. These formulations provide a simple way to treat circulating systems, such as cooling towers or swimming pools.

Suspensions/Dispersions

Suspensions or dispersions are either finely divided solid particles in a liquid or droplets of one liquid in another (emulsions). Either type of formulation will separate unless it is well mixed before and during use.

Aerosols

An aerosol is a suspension of fine particles or droplets in air. Use fog- or mist-generating machines to produce aerosols to treat large enclosed areas. Pressurized or nonpressurized-packaged aerosol formulations may be solutions or emulsions. A direction to shake well before using is a reminder to get a well-mixed suspension before applying the spray.

Gases

Gaseous antimicrobial pesticides are used to disinfect and sterilize where other agents cannot be used or where the use of a gas is dictated by the need. Gases may be supplied in pressurized containers, or they may be solids or liquids that are sprayed, heated, or evaporated to produce the active gases.

Ethylene oxide and its mixtures are supplied in pressurized cylinders. Formaldehyde may be purchased as a powder (paraformaldehyde) to be heated or as a spray solution.

Ozone gas is generated by ozone generators to disinfect potable water and to treat certain waste streams. Its purpose is to avoid the residual chloramines that result from normal chlorination of water and waste water effluent. Neither the generator nor the gas is registered, but the generators are regulated as devices.

Gaseous agents are always used in unoccupied, enclosed spaces. Special precautions are required to insure that they will work well and not harm the applicator or other people. Pay close attention to all label instructions. Temperature and relative humidity requirements are sometimes critical. Be sure to note the types of materials which the product may be used to treat and any required post-treatment procedures.

How Antimicrobial Agents Work

Antimicrobials can also be grouped according to the activity level they provide. Many antimicrobials work at more than one level. Read the label to find out what each antimicrobial agent will do. Know the limitations of its activity. Antimicrobial agents work in one or more of the following ways:

- Cidal or cide: Kill microorganisms by contact (bactericides, fungicides).
- Static or stat: Interfere with growth or multiplication of the microorganisms (bacteriostats, fungistats).
- Reduce the number of microorganisms (sanitizers).

FACTORS AFFECTING USE OF ANTIMICROBIAL PESTICIDES

Consider these factors when choosing an antimicrobial agent:

Types of Microorganisms

The types of microorganisms to be controlled will vary. Some are very resistant to specific chemicals, while others are easily killed. No one chemical kills all types of microorganisms under all conditions. Read the product label to learn what each chemical agent can do.

Number of Microorganisms

The number of microorganisms present may affect the speed at which they can be killed. A larger number of microbes may require longer exposure to the antimicrobial agent (see label directions). Where there are large numbers of microorganisms, as in fecal or other organic contamination, do not expect microbial agents to work. Clean the area before the antimicrobial agent is applied, even though the label may not say so.

Age and Condition of Organisms

Older microbial cells are more resistant to antimicrobial agents than younger cells. All antimicrobial agents work best when microorganisms are actively multiplying or dividing. Most agents have little or no effect on microbial spores.

In general, articles or materials exposed to soil or dust and kept dry have large numbers of bacterial and fungal spores. Articles or materials exposed to organic materials such as urine, protein, carbohydrates, and cellulose in the presence of water contain large numbers of growing bacteria and fungi in the vegetative cell state.

Nature of Surface

Porosity, smoothness, oiliness and other surface characteristics may affect the action of antimicrobial agents. Remember, the antimicrobial agent must contact the microorganisms to be effective.

Concentration

The amount of antimicrobial agent you apply influences its effectiveness. Follow label directions for properly diluting the product for use at the prescribed concentration.

Contact Time

Chemical agents never act on microorganisms instantly. Some function effectively within a few seconds; others may take hours. Follow the label directions. If the antimicrobial agent does not contact the microbial cell, it will be ineffective.

Hardness of Water

The hardness of water depends on the amount of calcium, magnesium and other chemicals present. Hardness may interfere with the killing power of some antimicrobial agents because of the reaction of these products with the calcium and magnesium hardness ions. Therefore, the label may set a hardness limit for the diluting water (expressed in parts per million of calcium carbonate). Determine the hardness of your local water supply by contacting municipal water supply officials or your local public health authority.

In circulating cooling water systems, suspended solids such as dust, dirt, mineral salts and organic contaminants can dramatically affect the quantity of certain biocide's required to produce the desired control. Quaternary ammonium compounds are readily absorbed on the surfaces of these contaminants and chlorine is quickly consumed by the organic particulates.

Acidity/Alkalinity (pH)

All antimicrobial agents and slimicides work best at some optimum level of acidity or alkalinity. Read the label to determine if acids or alkalis are required to help the disinfectant to work better by adjustment of the pH.

Composition and Amount of Soil on Surfaces

The presence of organic matter interferes with activity of most chemical agents. In hospitals, surfaces may be contaminated with blood, pus, tissue debris, sputum, urine or feces. In food preparation areas, fats or oils may be present. Because the inorganic matter protects the microorganism, it reduces and may completely stop the killing power of antimicrobial agents. Thus, the label may require very dirty materials to be exposed to a higher concentration of an antimicrobial agent for a longer time, or it may require the surface to be cleaned before the antimicrobial agent is applied. The surface to be disinfected must be clean in order for the disinfectant to work effectively. If it is not heavily soiled, clean and disinfect at the same time, but be sure the product is designed for this combined use. If the antimicrobial agent does not contact the microbes, it is ineffective.

Moisture or Humidity

Antimicrobial agents are ineffective without water or moisture. Either the relative humidity of the treated areas must be high, or water must be present in or on the material to be treated.

Temperature

With many antimicrobial agents, there is a relationship between the rate of action and an increase in temperature. Generally the agents are more effective as the temperature is increased.

EQUIPMENT, APPLICATION METHODS, AND CHEMICALS USED

It is important to understand the equipment you use to apply antimicrobial agents. Selecting the correct equipment may be the key to the success of the control program. You must also know how to use and maintain it. Use and care of all equipment for applying antimicrobial pesticides require special precautions.

Be sure to mix the product as the label directs. Do not combine different pesticides since a dangerous chemical reaction may occur or the resulting mixture may neutralize the combining agents.

Do not use equipment that has been used with one antimicrobial agent with another until it is cleaned and dried. Never make nonpesticidal applications with equipment that has been used with antimicrobials.

> Study only the section(s) in this chapter that you wish to be certified in: Industrial Cooling Water Systems, Swimming Pools, Hospital and Medical Services, Janitorial Services and Housekeeping, or Cleaning and Disinfecting of Poultry Houses.

Industrial Cooling Water Systems

Industrial processes which generate large quantities of heat often use water as the transfer medium to dissipate the heat and provide subsequent cooling or temperature control. Various heat transfer arrangements using cooling water are possible and range from a simple cooling tower for an office building to the complex systems found in the steel, food and beverage, pulp and paper, petrochemical and utility installations.

While these cooling water systems users may experience different and unique maintenance problems, all see the need for biological control and proper application of antimicrobials to insure efficient heat transfer and to minimize the added metal corrosion problems imposed by the presence of algal and slime growths. This biological contamination originates from the make-up water used in the system and, in open systems, from the air coming in contact with the water. The actual organisms, type and number, depends on the source of the water and if it is treated. For example, water from lakes, ponds, rivers and wells contains many microorganisms originating from the soil, while municipal water treatment plants produce water with the least contamination and highest quality. If the water is circulated in an open-system cooling process, airborne contaminants and nutrients also enter the system. Exposure to sunlight and the increased concentration of minerals in the water through water evaporation further increases the potential for proliferation of these microorganisms.

Cooling Water Systems

In most major installations requiring cooling water, there are three principal systems employed:

I. Closed recirculating systems

- The water is continuously recycled in a closed system wherein it is alternately warmed at the heat source and, through a suitable heat exchanger, it is indirectly cooled by air, water, or mechanical refrigeration.
- Systems are used for cooling internal combustion engines and compressors, and to provide heating and/or cooling in closed hot and chilled water system installations in office buildings, hotels, etc. . . .
- Systems use very little water and the water related problems of scale, corrosion, and biological fouling are minimized and treatment is simplified.

II. Once Through Systems

- Water of a suitable low temperature and from a primary source such as a well, river, or lake, flows through the cooling system and is discharged to waste.
- Since these systems use large volumes of water, they are used where water is plentiful and cheap.
- The only pretreatment is filtration or screening to avoid plugging or damage to system components.
- Water side problems depend on the source and quality of the water as well as the temperature rise in the heat transfer process.
- Chemical treatment for scale, corrosion, and biological fouling control is usually costly if the problems are severe because the water is not recirculated.
- Recent emphasis on water conservation and environmental concerns has encouraged abandonment of these systems where it is economically feasible.

III. Open Recirculating Systems

- Water continuously recirculates through process equipment wherein it is heated and returned to a spray pond reservoir or cooling tower and its temperature is reduced through evaporation.
- These systems permit economical heat removal, conservation of water through recycling, and reduced chemical treatment costs.
- The only makeup water needed is that to replace the water lost in the evaporation process, system leaks, and blowdown or intentional purging of the recirculating water to reduce the concentration of minerals or contaminants in the recirculating system.
- This type of system increases the potential for water-related problems because of the concentration effect.
- Air contaminated with microorganisms along with nutrients such as dust, dirt, and dissolved gases enter the recirculating cooling water system through the scrubbing action of the water spray. These contaminants become concentrated through evaporation of the recycling water and biological fouling becomes a major threat.

Several Open Recirculating Systems have been developed to recycle and conserve cooling water but the most widely used system is the cooling tower (Fig. 4).

Warm water is pumped from the process to the tower where it is distributed over and through a suitable tower fill consisting of wooden slats or synthetic honey-combed sections. The water cascades over the fill and closely contacts the counter-flowing air where maximum evaporation and subsequent cooling occurs. The cooled water reaches the tower basin and returns to the heat-generating process, completing the cycle. There are several different designs as follows:

- Mechanical Draft Towers have fans located at the top of the tower that draw in air at the tower sides and exhaust it upward. Examples are:
  Induced draft towers which include counter-flow (Fig. 5, air moves up through tower fill) and crossflow (Fig. 6, air moves horizontally across tower fill). In forced draft tower installations, air is blown into the tower from the side or bottom.
- Atmospheric spray towers (Fig. 7) are similar to mechanical draft towers but do not have

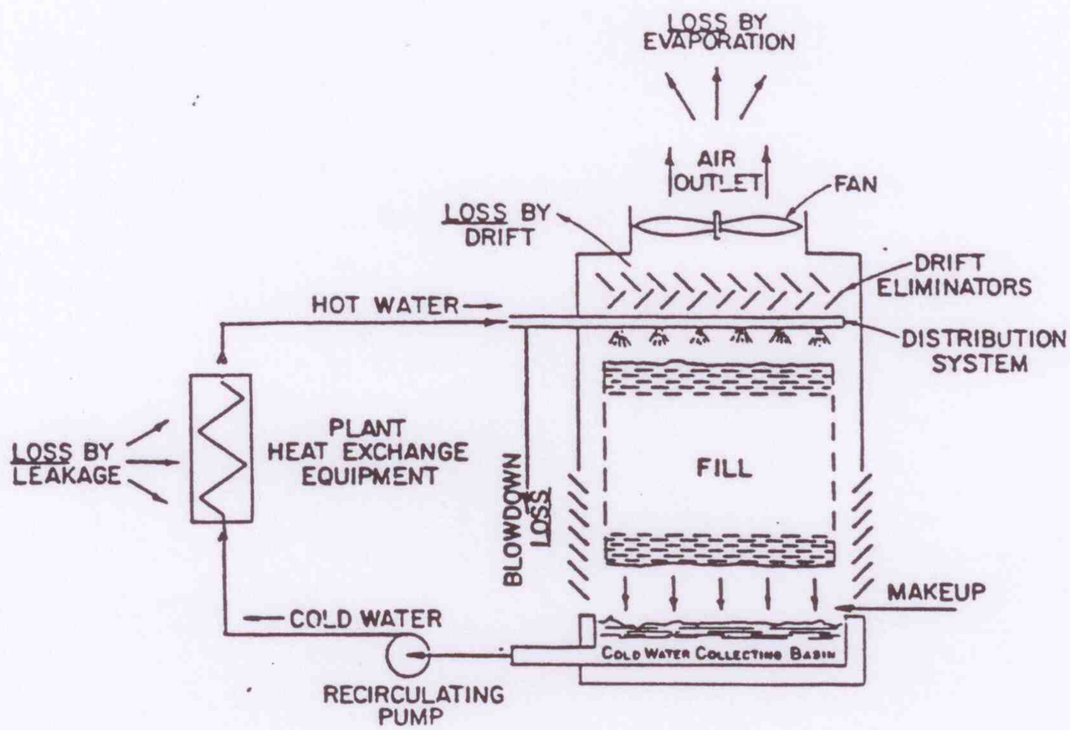

Figure 4. Typical cooling tower loop in open recirculating system with water loss areas indicated (Courtesy Buckman Laboratories, Inc.)

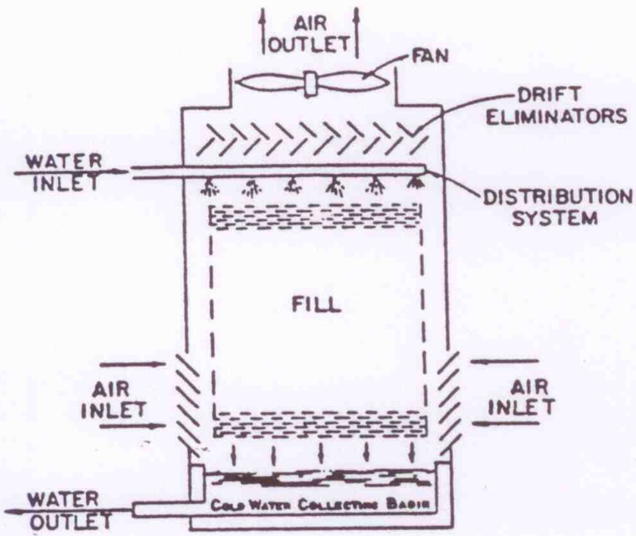

Figure 5. Induced-draft, counterflow cooling tower (Courtesy Buckman Laboratories, Inc.)

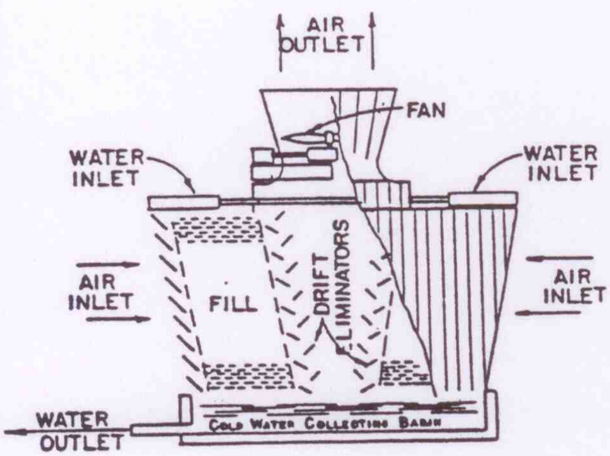

Figure 6. Induced-draft, crossflow cooling tower (Courtesy Buckman Laboratories, Inc.)

a fan. The cooling effect is produced by air movement and contact with the spraying water. Since normal wind currents must be relied upon to produce the air for cooling, few such towers are now in service.

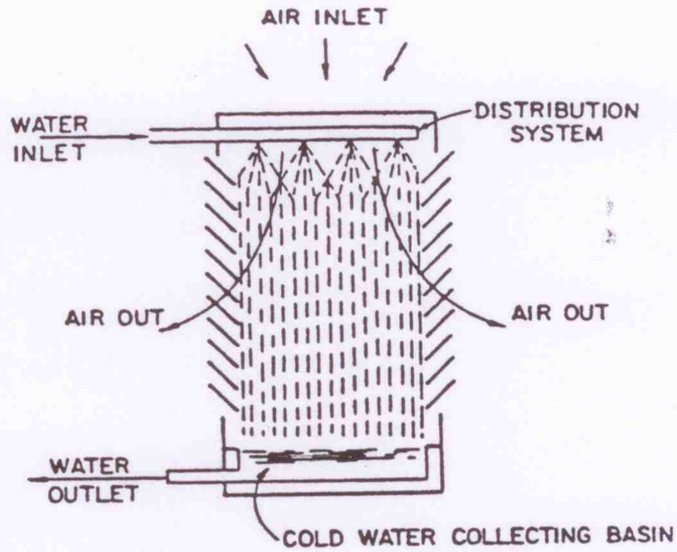

Figure 7. Atmospheric spray cooling tower (Courtesy Buckman Laboratories, Inc.)

Also included are hyperbolic or natural draft towers (Fig. 8) are utilized when very large amounts of heat must be dissipated such as in steam electric generating stations. Warm water is sprayed onto the tower fill of these unusually large (300-400 ft. high with a base diameter of 200-300 ft.) hyperbolic-shaped towers. The difference in the density of the resulting warm air inside the tower and that of the cooler outside air creates a 'chimney effect' and produces the air movement necessary for cooling the recirculating water. Some cooling towers have heat exchangers, such as evaporative condensers, mounted inside the tower wherein the recirculating water flows over the metal surfaces picking up heat which is subsequently lost as the water is cooled by moving air.

- **Air Washers (Fig. 9) represent a special case of an open circulating water system since such systems are designed to cleanse and condition air in a working environment. The textile industry employs this air washing equipment for cleaning plant air, controlling humidity and for heating in the winter and cooling in the summer.**
- The system consists of an enclosure with two open sides opposite each other equipped with vertical louvers on one side that evenly disperse the flowing air through the chamber and vertical mist eliminator louvers on the opposite side to remove water that is entrained in the flowing air.

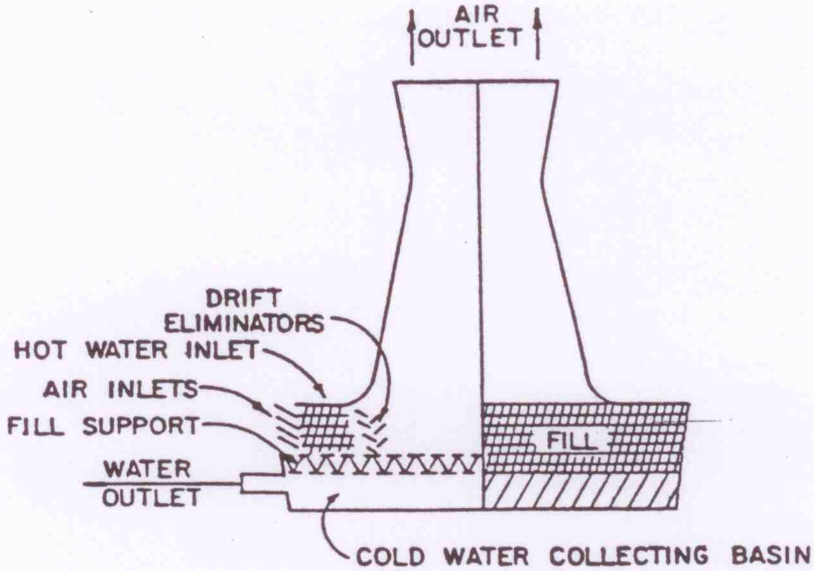

Figure 8. Hyperbolic, natural-draft cooling tower (Courtesy Buckman Laboratories, Inc.)

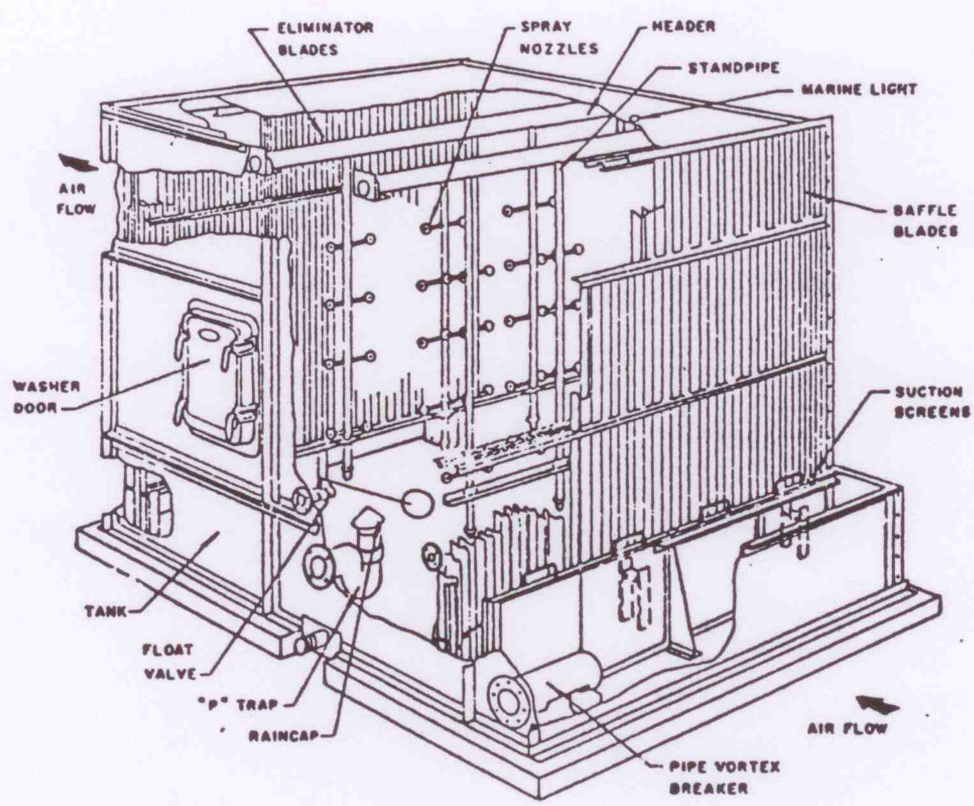

Figure 9. Air Washer Station (Courtesy Carrier Corporation).

- Inside the chamber, vertical headers equipped with spray nozzles are spaced across the area of air flow. Water is pumped from the sump to the nozzles so that the circulating air passes through a dense curtain of water droplets to provide the maximum contact between air and water.
- In many installations the air entering from the plant area is pre-filtered to remove lint, dust, dirt and oil with a drum roll filter, paper media, or some synthetic media.
- Severe air contaminant load requires a special water treatment program to control microbiological fouling that presents special corrosion problems.

Maintenance and Chemical Treatment

The illustrated circulating cooling water systems have water problems that require a good maintenance and chemical treatment program to insure maximum operating efficiences. These problems are briefly described as follows:

- Scale deposits are the result of the precipitation and adherence of concentrated minerals in the recirculating water due to exceeded solubility and/or the increased water temperature. These deposits interfere with proper heat transfer in the exchanger and may even plug tubes and prevent proper water circulation. Control of the concentration cycles and proper chemical treatment are necessary to minimize this condition.
- Corrosion of the system's metals is greatly intensified in open circulating water installations due to the intimate contact of water with the air, scrubbing out oxygen and other corrosive gases, airborne contaminants and particulate matter. Increased temperatures and the presence of deposits intensify the destructive corrosive effect of the circulating water. A proper maintenance program involves determining the corrosion source and administering the correct corrosion control treatment compounds.
- Fouling of the heat exchange surfaces is caused by the deposition of non-scale forming material such as mud, silt, suspended iron, airborne particulates and organic and inorganic matter entering the system with the make-up water. Fouling control can be established through the proper choice and use of polymeric dispersants and/or flocculants which will disperse the contaminant and allow it to be purged from the circulating water through the blowdown. Wetting agents or surfactants are used to emulsify water insoluble oils or hydrocarbon contaminants that may otherwise cause operating problems.
- Wood deterioration is a potential problem in cooling towers since wood is one of the basic materials of construction. Even though redwood and pressure-treated woods are used, their service life will be shortened unless steps are taken to prevent delignification due to chemical attack from strong oxidizing or highly alkaline agents. Certain biological organisms will also attack the wood, producing surface rot and internal decay. Erosion by flowing water and elevated temperatures will lead to the physical degradation of wood components and loss of structural strength.

Microbiological Growths

A detailed discussion of the preceding problems is not within the scope of this presentation but the problems must be recognized and solved as part of a good maintenance program that can affect the performance of the cooling system. Another major operating problem in open circulating systems is control of microbiological deposits which can severely interfere with proper heat transfer and cause fouling of equipment and corrosion of the system metals. Microbiological fouling of cooling towers and heat exchange surfaces is due to the uncontrolled growth of algae, fungi and bacteria. Contaminants originate from the make-up water used in the cooling system and from the air that mixes with the circulating water, giving rise to microbiological growths. The most common ones are:

- Algae, which produce their own food through photosynthesis, grow in spray ponds and in open areas of the cooling tower where sunlight, air and water are available. These growths can form masses that will block screens and holes in the distribution deck of the cooling tower severely impeding water flow. The most common forms are diatoms, and green and blue-green algae which may appear as long strands or as free-floating masses.
- Bacterial and fungal slimes may also be found in the tower fill sections and sumps but are most often found in the non-exposed areas of the recirculating system such as in pipes and on heat exchange surfaces. Deposits will range in color from off-white to dark brown dependent on the type of organism and on the particulates which may have been trapped in its adherent, gelatinous mass. The growth consistency can range from stringy and viscous to leathery or rubbery. As the

growths age or mature, they become highly resistant to treatment.

- Iron bacteria remove soluble iron from the recirculating water, oxidize it, and then deposit it as ferric hydroxide or iron oxide in the form of slime-like filaments. Growths can be severe enough to restrict water flow in pipes and tubes.
- Sulfate-reducing bacteria, unlike the aerobic organisms cited, require an oxygen-free environment in which to grow. They thrive in oxygen depleted areas under slime growths and other deposits in the circulating system. These bacteria produce corrosive and odoriferous hydrogen sulfide which is very detrimental to steel and other metal components of the system. These destructive organisms are hard to detect because of the locations in which growth occurs.
- Filamentous fungi may appear as black, brown, or green spots above the water line and on wood surfaces that are part of the cooling tower construction. These growths contribute to surface and internal decay of wood and do severe damage unless treated.

Control of microbial activity in cooling water systems is only one of the goals of a proper water treatment program. While it may be desirable to kill all microbes, it is usually too costly and unnecessary in industrial installations. These systems are therefore treated with the proper biocides to control microbial populations at levels that will not interfere with circulation and heat transfer. Choosing the proper biocides requires the expertise of a reputable water-treatment company and most often involves a survey of the system, identification of organisms present in the circulating water, and determination of tolerable population counts.

Antimicrobials for Cooling Water Systems

The following antimicrobials have been used successfully to control the organisms listed:

- Chlorine and chlorine releasing compounds. This oxidizing biocide is readily available at low cost and is toxic to most algae and bacteria at residual concentrations between 0.6 and 1.0 ppm for a short period. The amount required depends on the organic contamination load which will consume the chlorine. Over-feeding will cause delignification of any wood in the tower system.

The following biocides are classified as non-oxidizing:

- Chlorinated phenols. Although the use of sodium pentachlorophenol is banned, certain other chlorinated phenols find continued use as good over-all microbiocides. High concentrations are usually necessary for effective control.
- Quarternary ammonium compounds are good biocides that are effective over a wide pH range. They are sub-stantive to tower wood components and provide protection against fungi that attack the cellulose fibers and cause microbiological deterioration. "Quats" are absorbed by suspended solids, algae and slime masses and by other contaminants in the circulating water system. Unless these deposits can be mechanically cleaned from the system, additional product will be necessary to replace that so absorbed in order to establish the proper residual concentration. These compounds produce little odor and have surface active properties which facilitate penetration of the protective layer on most biological growths.
- Organosulfur compounds are highly effective against slime-forming bacteria, fungi, and sulfate reducers. High concentrations are usually required and the offensive product odor may restrict its use. They are not very effective against algal growths.
- Thiocyanates. Methylene bisthiocyanate is the most widely used product of this type. It is a good overall biocide, effective against algae and bacteria, and is not affected by organic contaminants in the circulating water.
- Organotin compounds are good overall biocides and are especially effective when combined with quats to produce a synergistic effect.

Because of the serious effects biological fouling has on equipment in once-through and open recirculating water systems, operators need to understand that these growths must be controlled. Slime and algal growths not only impede heat transfer but also add to the corrosion of system metals, causing severe pitting and reduction of the useful life of the equipment. To be effective, antimicrobials, whether biocidal or biostatic, must be administered so that a residual concentration is established intermittently for a minimum time period or so that a residual concentration is maintained continuously.

In once-through systems, it is not economically feasible to maintain a continuous feed of the antimicrobial to achieve a residual concentration. Therefore, an intermittent or "shock" dose is applied for the required time interval to effect a kill. This method allows biological growth to occur for a time and the organism is then "shock" treated for removal. Dosages, growth periods, and removal times will vary with each microorganism and system. The "shock" dosage method is also applicable to open recirculating systems unless the nutrient load, and thus the potential for algae and slime growth, is high. In such cases, the continuous treatment method is usually necessary, especially in certain cooling tower and air washer systems, so that a residual antimicrobial concentration is maintained to inhibit any growth beyond tolerable populations. By using two chemically different biocides on an alternating basis, better control is achieved than by using only one biocide. This procedure will prevent the development of a resistant strain of microorganisms that may otherwise be immune to a single biocide.

Automatic Feeding Equipment

For antimicrobials to function effectively, they must be administered at the proper concentration. Many industrial processes that require the use of antimicrobials utilize various types of feeding equipment to insure accurate and reliable addition of the proper chemical compound at predetermined concentrations. Such equipment is available for feeding both dry powders or solutions of antimicrobials at a fixed or variable rate. Through the use of timers, electrical pulse meters, or sensing probes the addition of antimicrobials can be automated. Municipal water treatment plants, the food and beverage industry, swimming pools, and cooling tower installations automate chemical additions using feeding equipment that includes one or more of the following components:

- Volumetric or gravimetric feeders.
- Positive displacement pumps.
- Water-jet eductors.
- Conductivity probes.
- Liquid level control switches.
- Metering valves.
- Timers.
- Electric pulse flow meters.

Advantages

- Antimicrobial agent can be added automatically to cleaning stream, tank or circulating cooling water system.
- Disinfectant solution can be maintained at the proper strength automatically.
- Consistantly good results may be obtained from the automated antimicrobial feeding system.

Limitations

- Pumps, timers, switches, and injection devices must be properly calibrated and set.
- Routine maintenance is required for consistent and reliable operation.
- Chemical tests may be necessary to verify proper feeding of biocides at required concentrations.

Hazards in Using Cooling Water Antimicrobials

Due to the chemical nature of antimicrobials, there is always some danger associated with their use. Understand and follow product label instructions and warnings precisely to avoid accidental exposure and possible physical harm. The dangers of some of the most commonly used cooling water antimicrobials are listed below:

- Chlorine Gas

  Use—Chlorine source for disinfecting water.

  Hazards—Poison gas causes severe eye, throat, and lung damage. Will burn skin on short exposure. Extremely harmful or fatal if inhaled.
- Sodium and Calcium Hypochlorite, Chlorinated Cyanurates

  Use—Chlorine source for disinfecting water

  Hazards—In dry forms and in concentrated solution these oxidizing chemicals can cause chemical burns or irritation to skin, nose or throat. Can cause severe damage to eyes. Harmful or fatal if swallowed.
- Quaternary Ammonium Compounds

  Use—Control of algae and bacterial slime growths.

  Hazards—Most are corrosive and can cause severe eye damage and skin irritation. Absorption through the skin will cause harmful effects and ingestion may be harmful or even fatal. These products are toxic to aquatic life forms and effluent containing these products should be properly discharged.
- Organotin Compounds

  Use—Formulated with quaternary ammonium compounds to control algae and bacterial slime growths.

  Hazards—Same as under Quaternary Ammonium Compounds.
- Organosulfur Compounds

  Use—To control fungi and bacterial slime growths and sulfate-reducing bacteria.

  Hazards—Cause eye damage and skin irritation. Harmful or fatal if swallowed or absorbed through the skin.

  Common examples—Potassium and sodium dimethyldithio-carbamate, disodium ethylenebisdithiocarbamate.

- Thiocyanates
  Use—To control bacterial slime growths and algae.
  Hazards—Same as organosulfur compounds.
  Common example—Methylene bis (thiocyanate)

First Aid Procedures—Because the antimicrobials are all corrosive to the eyes, skin, and mucous membranes, as well as harmful or fatal if swallowed, follow the procedures listed below in case of accidental exposure.

- In case of contact, remove contaminated clothing and immediately wash skin with plenty of soap and water. For eyes, flush immediately with copious amounts of water for at least 15 minutes. If irritation persists, seek medical attention. Wash contamined clothing before reuse.
- In case of ingestion, consult the individual product label since the first aid procedures differ among the products.
- If chlorine gas is inhaled, remove victim to fresh air immediately, and seek aid of a physician.

Swimming Pools

If we consider all swimming pool installations as an industry, it then represents a major consumer of antimicrobials. Most towns and communities operate public swimming pools for the benefit of their citizens. Private clubs and an ever increasing number of families have swimming pools which provide excellent recreational activities. State and municipal regulations require that public swimming pool facilities be maintained in a sanitary condition and likewise, private pool owners must maintain a water-treatment program using swimming pool care products that include various antimicrobials and other water-treatment compounds.

Pools are equipped with a recirculation and filtering system designed to recirculate the water in the pool every 6 to 12 hours. These "turnovers" are necessary to maintain water clarity and to distribute the treatment chemicals uniformly. The water must be treated since little fresh water is added other than that to make up for evaporation, backwashing or splashing.

Because swimmers inadvertently swallow pool water while swimming, the bacteriological water quality must closely resemble drinking water. Since the pool is being constantly contaminated by bathers, antimicrobials must be present at residual concentrations to disinfect the water before any inadvertent ingestion. The disinfecting chemicals may be added on a continuous basis to the recirculating water with proportioning pumps or automatic feeders, as with large pools, or added intermittently by hand. In both cases, the pool operator uses test kits to correctly measure certain water characteristics such as pH, hardness, alkalinity, and disinfectant residual concentration in order to adjust addition of the proper treatment compounds that maintain the necessary chemical balances. Commercial test kits and detailed instructions are readily available from pool supply companies and manufacturers of pool-care products.

For maximum bather comfort, aesthetic water qualities, and safety against infection from disease-causing microorganisms, the water chemistry must be in proper balance. To achieve this balance, specific guidelines have been established for the use of pool-care products in adjusting the water to the proper control ranges. These parameters, pool-care products and control ranges are discussed:

Control of pH

This value is based on a scale of zero to 14, with seven being neutral. It represents the acid-base balance of the pool water and values below seven measure degree of acidity with the lower numbers being more acidic. Values above seven are progressively more alkaline as the index number increases.

Ideal Range: 7.2 to 7.6

Chemicals:

- To lower the pH, an acid such as liquid *muriatic acid* or powdered *sodium bisulfate* is used.
- To raise the pH, alkalis or bases such as *soda ash* or *bicarbonate of soda* are added.

Advantages:

- Within proper range maximum bather comfort is realized and there is the least corrosion to metal parts.

Disadvantages:

- Outside the range, irritation to eyes and mucous membrane, mild skin discomfort, corrosion of metal parts, and excessive chlorine consumption may occur.

Control of Total Alkalinity

Certain dissolved minerals in the water contribute to the total alkalinity of the water and these compounds exist in the water in the form of bicarbonate, carbonate and hydroxide ions. Depending on the form and its concentration, it will directly affect the pH of the pool water. The bicarbonate form is most desirable and it exists within the pH range of five to nine. Between the pH range of 8.3 to 10, both bicarbonate and carbonate exist and above 10, the undesirable hydroxide form exists. Proper control of alkalinity makes it easier to maintain the pH within the desired range.

Ideal Range: 80 to 120 parts per million

Chemicals:

- To lower the alkalinity, use an acid such as liquid *muriatic acid* or powdered *sodium bisulfate.*
- To raise the alkalinity, add alkalis or bases such as *soda ash* or *bicarbonate of soda.*

Advantages:

- Within proper range maximum bather comfort is realized and there is the least corrosion to metal parts.

Disadvantages:

- Excessive hydroxide and carbonate alkalinities that exist above a pH of eight can be irritating to swimmers' eyes. Alkalinities that are too low will cause staining by metal deposits and corrosion of pool surfaces and equipment.

Control of Iron

Dissolved iron is not a problem since it is easily oxidized by the chlorine added to the water and by the oxygen contained in the water. The oxidized product, ferrous hydroxide and ferric oxide may produce stains on certain pool surfaces unless properly controlled. Efficient filteration systems trap the oxidized product and prevent its settling out to cause unsightly stains. Certain organophosphonate products are available commercially to treat pools that have excessive iron contamination. Proper control of pH and alkalinity minimizes corrosion of iron-containing metals in contact with the pool water.

Control of Hardness

This refers to the "soap-consuming" capacity of the water and is directly related to the concentration of calcium and magnesium ions present as dissolved minerals. Iron, manganese, and other heavy metal ions in solution also contribute to hardness, but their concentrations are usually too low to be significant.

Ideal Range: 50 to 250 ppm

Chemicals:

- To raise the hardness, use *calcium chloride.*
- To lower the hardness, a portion of the pool water should be drained and the pool refilled with fresh water having a lower hardness that will "dilute out" or reduce the overall pool water hardness.

Advantages:

- Within the Ideal Range, maximum bather comfort is realized and minimum corrosion and scale build-up occurs.

Disadvantages:

- Hardness concentrations much above the range will cause cloudy water due to the precipitation of calcium salts and build-up of scale in the circulation system and on pool surfaces. These suspended solids encourage algae and bacterial growth, making microbiological control more difficult and cause bather discomfort.

Control of Microbial Growths

Bacteria and algae microorganisms are continuously introduced into pool water by swimmers, rain, dust, dirt and by organic contamination such as leaves, grass, etc. Proper control of these organisms requires a constant residual concentration of an antimicrobial to properly disinfect the pool water and make it safe for swimmers. State and local health laws require that swimming pools be maintained to prevent the spread of diseases and infections that affect the skin, eyes, ears, nose, throat, and digestive system organs. The most commonly used antimicrobials for swimming pool disinfection are the halogens, and although bromine and iodine are becoming increasingly popular, chlorine usage still dominates the field.

Ideal Range: 0.6 to 1.0 ppm (non-stabilized pools)
1.0 to 1.5 ppm (stabilized pools)

Chemicals:

Chlorine and chlorine-releasing compounds.

Advantages:

- Low cost and availability.
- Bactericidal effectiveness.
- Algaecidal effectiveness.
- Good oxidizer (burns up "organic" matter).
- Easily applied.
- Accurate test simplifies maintenance of proper concentration.

Disadvantages:

- May produce objectionable taste or odor.
- Can cause eye and nose irritation.
- Compounds harmful if misused
- Readily consumed by organic nitrogen compounds introduced by bathers.
- May be corrosive to swimming pool surfaces and equipment.

Chlorine and Chlorine-Releasing Compounds

Regardless of the source of chlorine, the important reaction that occurs in water to produce the active ingredients is as follows:

$$\underset{\text{Chlorine}}{Cl_2} + \underset{\text{Water}}{H_2O} = \underset{\text{Hypochlorous Acid}}{HOCl} + \underset{\text{Hydrochloric Acid}}{HCl}$$

The chlorine and hypochlorous acid shown in the equation above, when present at the proper concentrations, react with and destroy certain enzymes that are necessary for bacterial growth, thereby providing the disinfecting power needed. The powerful oxidizing ability of these chlorine compounds to destroy many different kinds of organic matter that cause color, taste and odor in the pool water arises from the decomposition of hypochlorous acid to produce 'nascent' monoatomic oxygen:

$$\underset{\text{Hypochlorous Acid}}{HOCl} = \underset{\text{Hydrochloric Acid}}{HCl} + \underset{\text{Monoatomic Oxygen}}{O}$$

The effectiveness of bacteriological control using chlorine depends upon the pool operator's ability to maintain the necessary chlorine residual concentration. The chlorine amount required to react with the organic contaminants, over a time period and produce this residual chlorine concentration is called the "chlorine demand" and is dependent upon these factors:

- pH.
- Temperature and weather conditions.
- Dissolved minerals.
- Organic and inorganic contamination.
- Bather load.
- Microbial growths.

The following antimicrobial compounds are commercially available as sources for chlorine used in swimming pool water disinfection. The product choice depends on the size of the pool and chlorine requirement, feeding equipment and operator training and capabilities, and above all, the proper label directions for use in pools. Antimicrobial products without directions for pool use are strictly forbidden by state and federal pesticide laws.

Chlorine gas—Cl_2 is sold in high pressure steel cylinders as a liquid. Upon release through a chlorinator, it becomes a gas that readily dissolves in water to form the active ingredient, hypochlorous acid, and the undesirable hydrochloric acid. Use of chlorine gas requires the addition of alkali (See Control of pH) to neutralize the acid. Chlorine gas is extremely dangerous and should be administered only by a thoroughly trained operator.

Sodium hypochlorite—NaOC1 is known as liquid chlorine and is sold as a 15 percent solution that readily mixes with water to provide a source of chlorine. This product is commonly used, and since it is slightly alkaline, addition of acid (See Control of pH) is necessary to maintain the pH within the proper range.

Calcium hypochlorite—$Ca(OC1)_2$ is a dry powdered chlorine form usually containing 65 to 70 percent available chlorine. It is also available in both granular and tablet forms which dissolve at different rates in water to produce the active ingredient. It may be dissolved in water and fed to the pool using a hypochlorinator or it may be added directly to the pool water. It is most commonly used ~~in~~ private and small pools because of ease in handling and application.

Cyanuric acid and chlorinated cyanurates—Cyanuric acid and its non-chlorinated salts can be added to swimming pool water to "stabilize" the separately added chlorine and help prevent its loss due to decomposition by sunlight. This addition slightly diminishes the bactericidal efficiency and therefore requires an increase in the residual chlorine from the range 0.6 to 1.0 ppm to 1.0 to 1.5 ppm. Normal practice is to add three to four pounds of cyanuric acid for each 10,000 gallons of water to establish a stabilizer level of 30 to 50 ppm.

The same effect is achieved over a period of time using chlorinated cyanurates for disinfection. This group of products is composed of the sodium and potassium salts of dichloro-isocyanurate as well as *di* and *tri* chloro-isocyanuric acid. The most widely used of these products is sodium dichloro-isocyanurate and none leave any insoluble residues in the water.

Although chlorine is an effective bactericide at residuals between 0.6 and 1.0 ppm, higher concentrations of five to 10 ppm are required to kill algal growths; at this high concentration irritation to the bather's eye, nose, and mucous membranes occurs. Algal spores enter the pool water from rain, dust, leaves, and are best controlled using an algaecide such as the quaternary ammonium chlorides (See Chemical Groups) along with the chlorine used for bacterial control. If the algal growth is uncontrolled, it can quickly form an "algal bloom" and saturate the pool water causing excessive chlorine consumption, clog filters, and producing unsightly conditions.

Normally, very low concentrations (two to five ppm) of the quaternary antimicrobials will effectively rid the pool of algal contamination. While caution must be exercised in handling the concentrated biocide, the end-use levels pose no health problems to the swimmers. Carefully observe label directions.

Handling Pool Care Products

All of the pool-care products described are designed for use at specific dosage rates to adjust the water parameters in the pool to provide maximum comfort and health safety for the swimmer. The pool operator must have knowledge of product use and expertise in testing for chemical residuals and making required adjustments to maintain the necessary chemical balance. Never mix pool chemicals since there is danger of explosion and severe injury. Follow product labels and instructions exactly and store the chemicals in a cool dry place out of reach of children. Keep containers closed and avoid contact of the chemical with skin, eyes, and clothing. Have the operator test the pool water daily using reliable test kits which should be replaced at least annually. Finally, the operator must familarize himself with first aid procedures in case of an accident or mishandling of the pool-care product.

Feeding Equipment for Chlorine Products

Pool operators may choose chlorine gas, sodium hypochlorite solution, dry calcium hypochlorite, or one of the chlorinated cyanurates as a chlorine source that best meets the need for pool chlorination. The pool size and load, available trained personnel, mixing, feeding, and testing equipment are important in deciding which product to use. For example, chlorine gas use is usually confined to large pool installations because special feeding and safety equipment and a trained operator on constant duty are required when the pool is in use. Automatic feeding equipment has been developed to reliably dispense the selected product to provide the chlorine source. These devices are:

Chlorinator—This equipment dispenses the chlorine from either a stationary or portable high-pressure steel cylinder. Chlorine gas becomes a liquid under sufficient pressure and when released from the cylinder returns to its gaseous state. Special fittings connect the pressurized cylinder to a V-notch valve and flow-meter where the gas is mixed in controlled amounts of water which is then added to the pool. Routine analyses for chlorine residuals are performed and the valve adjusted accordingly to produce the required flow rates for proper chlorine concentrations.

Advantages:

- Chlorine gas is a good, economical source of chlorine as a disinfectant.
- Equipment requires minimum storage space.
- With proper maintenance, equipment provides accurate and reliable feed rate for the chlorine gas.
- Feed rates are easily changed and equipment provides good automatic operation with minimum attention.

Disadvantages:

- Chlorine gas is extremely dangerous and must be handled with care.
- Pressurized cylinders of chlorine gas should be handled only by well-trained personnel because of the severe dangers involved.
- Observe safety precautions in the use, storage, movement, and repair of chlorinators and attendant equipment.
- Make available proper protective equipment such as a gas mask and protective clothing in case of a chlorine leak.
- Predetermine emergency procedures and evacuation plans to protect the public in case of an accident or malfunction of equipment that might release chlorine gas.

Hypochlorinator—This equipment dispenses sodium or calcium hypochlorite or dichloroiso cyanurate. A storage tank provides the concentrated chlorine solution to a positive-displacement proportioning pump that injects a predetermined volume of solution into the circulating pool water to produce the required chlorine residual. The pump may operate continuously or be controlled by a timer, as conditions may require.

Advantages:

- Automatically provides a reliable feed rate of concentrated chlorine solution to pool water.
- Equipment is readily available and relatively inexpensive.
- Solutions of the proper chlorine concentration are easily made in the storage tank, requiring minimum labor.
- Feed rates are easily changed by adjusting the pump or timer settings.

Disadvantages:

- Solutions of chlorine in the feed tank may deteriorate upon prolonged storage and at elevated temperatures.
- Pump fittings and lines must be periodically acid cleaned to remove residues in solutions of sodium and calcium hypochlorite.

Other—If the source of chlorine is in a slow-dissolving stick or tablet form, use by-pass cartridge feeders and floating dispensers. Circulating pool water flows through the feeder containing the chlorine product and slowly dissolves the powder. These feeders can be regulated to change the water flow and thus the amount of chlorine produced. These feeders are normally used in small or home pool installations and are not as reliable as the equipment previously described.

Finally, the dry chlorine product may be added manually to the water by broadcasting over the pool surface or adding to the skimmer or filter inlets. Frequent testing is necessary to insure proper chlorine residuals.

Hazards in Using Pool-Care Products

Severe injury or even death may result from accidents caused by mishandling pool chemicals. These products and some of the possible hazards associated with their use are identified as:

- Muriatic Acid and Sodium Bisulfate
  Use—To lower pH and alkalinity of pool water.
  Hazards—Both products are poisonous. Vapors of the liquid muriatic acid will burn eyes, throat, nasal passages, and muscous membranes. Both products cause severe eye and skin burns and may be fatal if swallowed.
- Soda Ash and Bicarbonate of Soda
  Use—To raise pH and alkalinity of pool water.
  Hazards—Causes severe eye and skin burns. Harmful or fatal if swallowed.
- Calcium Chloride
  Use—To raise the hardness of pool water.
  Hazards—Causes severe eye and skin burns. Harmful or fatal if swallowed.
- Chlorine Gas
  Use—Chlorine source of disinfecting pool water.
  Hazards—Poison gas causes severe eye, throat, and lung damage. Burns skin on short exposure. Extremely harmful or fatal if inhaled.
- Sodium and Calcium Hypochlorite, Chlorinated Cyanurates
  Use—Chlorine source for disinfecting pool water.
  Hazards—In dry forms and in concentrated solution these oxidizing chemicals can cause chemical burns or irritation to skin, nose or throat. Can cause severe damage to eyes. Harmful or fatal if swallowed.
- Cyanuric Acid or its Sodium and Potassium Salts
  Use—As a chlorine stabilizer in pool water.
  Hazards—Causes skin and eye irritation. Harmful if swallowed.
- Aluminum Sulfate
  Use—To floc or settle out suspended solids to clarify pool water.
  Hazards—Causes skin and eye irritation. Harmful if swallowed.
- Quaternary Ammonium Compounds
  Use—To control algal growth in pool water.
  Hazards—Causes severe eye and skin burns. Harmful or fatal if swallowed.

First Aid Procedures—Since antimicrobials are all corrosive to the eyes, skin, and mucous membranes, as well as harmful or fatal if swallowed, follow these procedures in case of accidental exposure.

In case of contact, remove contaminated clothing and immediately wash skin with plenty of soap and water. For eyes, flush immediately with copious amounts of water for at least 15 minutes. If irritation persists, seek medical attention. Wash contaminated clothing before reuse.

If ingested, consult the individual product label since the first aid procedures differ among the products.

If chlorine gas is inhaled, remove victim to fresh air immediately and seek aid of a physician.

Hospital and Medical Services

Gas Sterilizers

A gas sterilizer (Figure 10) is a closed chamber in which gases are used to kill bacteria, viruses and other microorganisms. The gas penetrates better if a vacuum is created in the chamber. Ethylene oxide (EO) is the most common gas used.

Sterilizers range in size from less than five cubic feet (0.14 cubic meters) to more than 100 cubic feet (2.8 cubic meters). The small units may be operated with manual controls at room temperature, or, like the larger units, may have fully automatic controls which often include built-in humidity controls.

Advantages:

- Ability to sterilize a wide variety of medical articles and materials that would be destroyed in a steam sterilizer.
- Ability to sterilize materials in a suitable package and maintain sterility after removal of the package from the sterilizer, if proper precautions are taken.
- Ability to chemically and biologically monitor the materials placed in the sterilizer for the presence of the gas and the correct functioning of the sterilizer.

Limitations:

- Chemical burns and skin and mucous membrane irritation may result when items such as surgical instruments and catheters are not properly aerated after treatment.
- Porous items absorb gas during processing. Time is needed to allow the absorbed

gas to dissipate. Knowledge of aeration time is required.

- The gas cannot penetrate such materials as glass, metal and foil.
- Use wrapping material that gas can penetrate easily—do not use nylon, polyester, or foil.
- Sterilization takes a relatively long time (three to 12 hours).
- There is a potential hazard to operators where venting is inadequate.

Use EO sterilization only when the items cannot withstand steam sterilization. Be sure to follow the manufacturer's operating instructions exactly. Remember the following when using this type of equipment:

- Install the EO sterilizer in a large, well-ventilated room.
- EO should not exceed an average of 50 ppm over an eight-hour period any time when people are in the room.
- Properly ventilate the sterilizer and aerator. This may mean venting to the outdoors or to a stream of running water such as a water-operated vacuum pump.
- Never let the temperature in areas where EO cartridges and cylinders are stored exceed 85° F (29° C).
- When the label warns that an EO product is flammable or explosive, post visible DANGER and NO SMOKING signs in all areas where it is used or stored.
- Open the sterilizer door for five minutes before removing sterilized materials. This allows residual ethylene oxide in the chamber to dissipate.
- Report any skin, eye, and throat irritations, as well as nausa, dizziness, and disorientation immediately.
- A color-change tape is available as a quick chemical indicator of whether exposure of products has occurred. A biological indicator consisting of bacterial spores is also available to confirm that sterilizing conditions were achieved. Use both indicators for adequate control.
- Follow the manufacturer's instructions carefully. If you notice any malfunction, shut off the EO sterilizer and notify maintenance personnel.
- Properly aerate all items undergoing gas sterilization in accordance with the guidelines published by the Association for Advancement of Medical Instrumentation (AAMI).

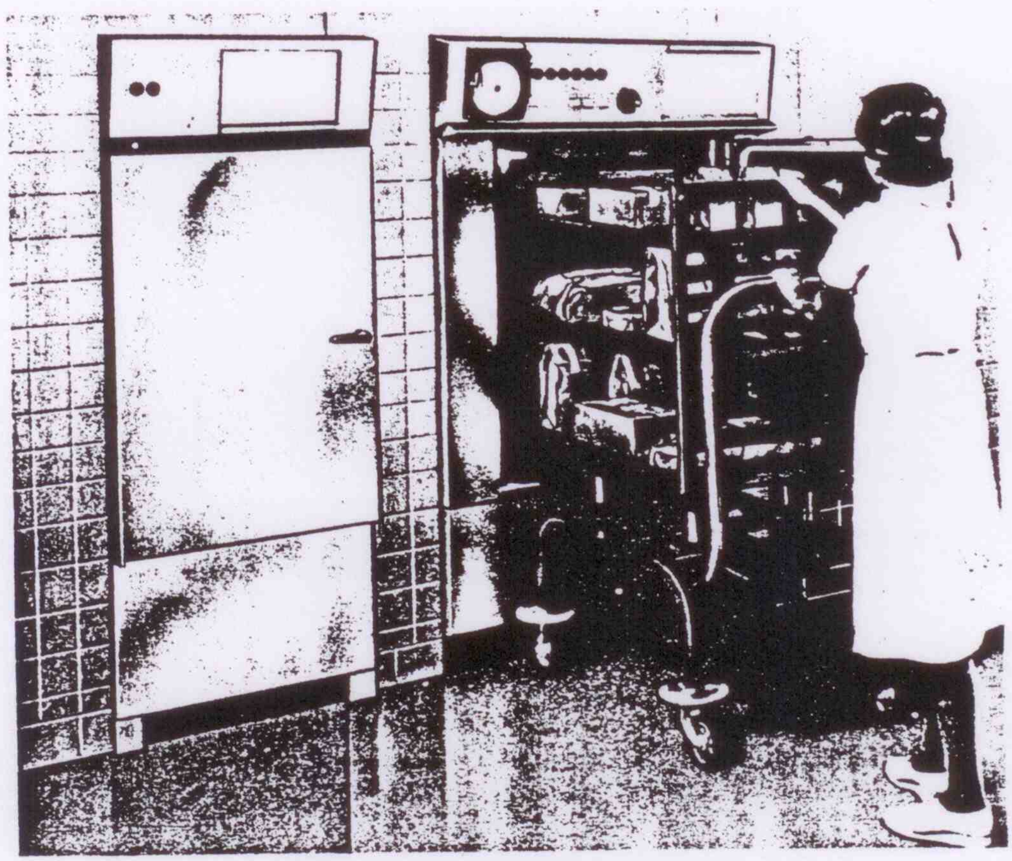

Figure 10. Gas sterilizer (Courtesy of American Sterilizer Co.)

Formaldehyde Vacuum Process

In this process, a vacuum device is used to remove part of the air from the chamber of a pressurized container. Steam is then admitted, and then formaldehyde gas. The steam heats the articles, maintains the temperature, and causes the formaldehyde to penetrate better.

Limitations:

- Use is restricted to certain unwrapped instruments, articles, and areas: not used for general sterilization.
- Penetration is slow.
- Porous items absorb gas during processing. Time is needed to allow the absorbed gas to dissipate.

Fumigators

This process can be used for room disinfection. A heat source (such as an electric frying pan) is used to vaporize para-formaldehyde in an enclosed space to kill microorganisms. Control the humidity and temperature or results will be poor.

Advantages:

- Disinfection of well-exposed surfaces is possible.

Limitations:

- Gas concentration is difficult to control. It requires the room to be sealed. This is difficult to achieve in large rooms.
- High risk of accidental exposure.
- Requires prolonged airing to remove deposited surface films or paraformaldehyde.
- Does not disinfect unexposed surfaces and does not penetrate porous materials.
- Recommended or necessary only in special research, "hot laboratory" or "exotic disease" situations.
- Should be used only by well-trained and experienced operators.

Hazards of Gas Sterilizer Products

- **Ethylene Oxide (EO) Hazards—Product is unstable if heated and may undergo explosive polymerization. Pure EO is flammable. Gas is irritating and liquid is corrosive. EO can cause severe eye damage and chemical burns to the skin. If ingested, causes corrosive damage to mucous membranes of mouth and throat.**

  First Aid—Remove contaminated clothing and wash skin or eyes with cool water for at least 15 minutes. For eyes, seek medical attention. If ingested, contact a physician. Give artificial respiration if necessary.

- Formaldehyde Hazards—Product will burn skin and eyes. Vapors are irritating and will cause coughing, nausea and vomiting.

  First Aid—Remove contaminated clothing and flush skin and eyes with water for at least 15 minutes. If irritation persists, contact a physician. If ingested and victim is conscious, induce vomiting. Afterwards give milk or raw egg and call a physician.

- Paraformaldehyde Hazards—Solid material is a skin and eye irritant and if ingested will cause nausea and vomiting. Vapor may also irritate mucous membrane of mouth and throat.

  First Aid—Remove contaminated clothing. Flush skin and eyes with copious amounts of water for at least 15 minutes. If eye irritation persists, consult physician. If ingested, give milk or egg white and consult doctor.

Non-Chemical Devices

Surgical instruments and attendant articles undamaged by high temperatures may be successfully sterilized using an autoclave which is a pressurized steam heated vessel. Expose the article to be sterilized to high temperatures for the required time to kill all pathogens. Wet steam, hot water and dry heat are also used for disinfecting contaminated articles prior to use. For example, cooking and eating utensils are sanitized when subjected to minimum 180° F wash and rinse cycles.

Environmental Disinfectants

Hospitals and health care facilities must use many different cleaning agents and antimicrobials to insure that the environment is clean and meets the required standards of hygiene. Develop a rational policy for the use of disinfectants to insure that the proper antimicrobials are used at the required concentrations and in the appropriate areas to produce clean and sanitary conditions that prevent the spread of infectious diseases and maintain the patients' confidence. Application of antimicrobials is normally part of a good housekeeping policy and is discussed in greater detail under **Janitorial Services and Housekeeping** section.

Fogging and Spraying Applications

An antimicrobial agent is dispersed by an automatic sprayer or atomizer. Application stops when all exposed surfaces are wet. The equipment should be designed to do the job, be durable, and provide ease in operating, filling, and cleaning.

Where used, fogging is only an adjunct to other methods of disinfection.

Advantages:
- May remove floating infectious particles from the air.

Limitations:
- Remove bacteria that remain on the floor and horizontal surfaces by mechanical cleansing, regardless of whether fogging has been used.
- Soil on surfaces may keep the disinfectant from coming into direct contact with the microorganisms.
- Potentially hazardous to personnel.

Janitorial Services and Housekeeping

Routine cleaning of the environment including floors, toilet, locker room, bathing facilities and furniture is necessary to produce conditions that inhibit the development and possible spread of infections. Institutions such as hospitals, medical care facilities, schools and industry must develop a policy of janitorial maintenance procedures that prevent cross-contamination and protect the people who occupy and use the facilities. In most instances, a cleaning program utilitizing soaps and synthetic detergents is sufficient to remove soils and attached pathogens on floor areas. Toilet, locker room and bathing facilities may require the use of a cleaner-disinfectant that either kills or inhibits the growth of any bacteria on these surfaces. If an occupant has a highly contagious disease that poses a hazard to others in the facility, special sanitizing procedures using specific antimicrobials may be necessary to render the area germ-free.

The following antimicrobials are the most commonly used disinfectants:

- Phenolics

  Advantages:

  These inexpensive and readily available antimicrobials are active against a wide range of bacteria. They are fungicidal, kill some viruses and are used mainly for environmental disinfection.

  Disadvantages:

  These compounds are too corrosive or toxic for skin treatment, show no activity against bacterial spores and should not be used in food preparation areas or on equipment that may contact mucous membranes.

- Hypochlorites

  Advantages:

  Solutions of this inexpensive and readily available antimicrobial are easily made and used. The compound is active against viruses, bacterial spores and other pathogens due to release of free chlorine. Useful on most hard surface areas and is especially good for disinfecting food preparation areas. Available in solutions, powders and tablets.

  Disadvantages:

  Solutions of the compound have limited stability and are readily inactivated upon contact with organic matter. The solutions are corrosive to skin and eyes and may damage certain materials and surfaces. Compatability with detergents is limited and addition of acid to the solution must be avoided to prevent release of free chlorine which is extremely dangerous.

- **Iodine and Iodophors**

  Advantages:

  Iodine is available as a one percent active product in alcohol and as a complex organic compound or iodophor. The products are highly active against a wide range of pathogens and are most often used on the skin for pre-operative scrub procedures. Iodine shows sporicidal activity on the skin and is non-irritating and easy to use.

  Disadvantages:

  Products containing this antimicrobial are expensive and are therefore not generally used for environmental disinfecting procedures. Solutions are de-activated by aluminum surfaces.

- **Quaternary Ammonium Compounds**

  Advantages:

  Solutions are basicly inexpensive, easy to use and widely applied in food processing areas, locker rooms, toilet and bath areas as well as garbage storage areas. The product is effective against a broad spectrum of bacteria, acts as a virucide and fungicide and inhibits the growth of mold and mildew. Some formulations of this product are used as sanitizer-cleaner solutions for cleaning and disinfecting environmental areas in one step. Also, formulations are made using this antimicrobial along with muriatic acid as a toilet bowl cleaner to remove iron and scale stains and sanitize simultaneously.

  Disadvantages:

  Solutions are corrosive to both skin and eyes and are de-activated through contact with soaps, anionic detergents and heavy soil accumulations. Anti-microbial activity is good against gram-positive organisms but more limited against gram-negative organisms.

- Miscellaneous Antimicrobials
  Certain other antimicrobials find very limited and narrow use in housekeeping procedures. For example, pine oil may be used more often in residential environments than in institutions because of the residual odor and limited activity against many organisms. The aldehyde, glutaraldehyde, is used instead of alcohol solutions of formaldehyde because it is less irritating and corrosive while still very effective against vegetative organisms. Predominant use is confined to sterilization of non-porous articles. Solutions of ethyl alcohol are used as a disinfectant and anticeptic for clean, hard surface areas and for rapid disinfection of the skin. Oxygen containing compounds find use as laundry aids in sterilizing bed clothing and garments that have been contaminated with infectious pathogens.

Whether the janitorial and housekeeping procedures are performed by an in-house staff or outside contractor, it is mandatory that a policy be established to outline the requirements and goals that must be maintained. Users must be trained in the procedures to understand the need for using different antimicrobials in specific environmental locations. Closely follow potential hazards, proper concentrations of the antimicrobial, cleaning procedures, handling and storage requirements. Make a review of the effectiveness of the maintenance program periodically to insure that proper hygienic conditions are maintained. Laboratory analyses of swabs taken from critical areas such as operating rooms may be necessary.

Manually Operated Devices

These devices include such things as:

- Mops, sponges, brushes, cloths.
- Sprinkling cans.
- "Pistol-grip" sprayers.
- Aerosol containers.

Advantages:

- Physical "scrubbing" helps to clean surfaces so that the antimicrobial agent can come in contact with the microorganisms.
- "Pistol-grip" sprayers permit effective control of microorganisms where product is applied.

Limitations:

- Pressurized aerosols can only spot-disinfect articles or surfaces.
- Frequent changes of disinfectant solution are necessary as soil increases in bucket.
- Rates of application may vary.

Figure 11

Steam Cleaners and High Pressure Washers

These machines use the advantage of heat and the force of high-pressure water to effectively dislodge and remove dirt and particulate accumulations on hard surface areas. The proper antimicrobial or disinfecting agent is proportioned into the cleaning steam to effectively reduce the bacteria count on the surfaces.

Advantages:

- Physical force of high pressure stream helps to remove contaminants so that the antimicrobial agent will be more effective.
- Large surfaces and irregular objects may be more easily cleaned and disinfected.
- The strength of the disinfectant solution may be easily varied by adjusting the individual machine's injection rate.

Limitations:

- These machines are normally bulky and not easily transported.
- Auxiliary power source (gas, fuel oil, electricity, etc.) is necessary for machine operation.
- Worker requires training to successfully operate these machines.

Fogging and Spraying Applications

An antimicrobial agent is dispersed by an automatic sprayer or atomizer. Application stops when all exposed surfaces are wet. The equipment should be designed to do the job, be durable, and provide ease in operating, filling and cleaning.

Where used, fogging is only an adjunct to other methods of disinfection.

Advantages:

- May remove floating infectious particles from the air.

Limitations:

- Bacteria that remain on the floor and horizontal surfaces must be removed by mechanical cleansing, regardless of whether fogging has been used.
- Soil on surfaces may keep the disinfectant from coming into direct contact with the microorganisms.
- Potentially hazardous to personnel.

Cleaning and Disinfection of Poultry Houses

The ultimate goal of a disinfection program for poultry houses is to improve the health and performance of the birds. Achieve this by reducing the stress from pathogenic organisms (viral, bacterial, fungal, and parasitic) in the bird's environment. Total elimination of these agents of disease is difficult, if not impossible. We can only hope to reduce their numbers as much as possible through careful planning of our cleaning and disinfection programs.

Disinfection of poultry houses presents an enormous challenge. Most poultry houses in the United States are shelters constructed of cinder blocks, cement, wood, roofing tin, curtains, wire and insulation. They are filled with the equipment necessary for providing the birds with food, water, fresh air and heat. Dirt floors and dusty conditions are common. This is not the easiest environment to disinfect.

The general principles, procedures, and antimicrobials recommended for the poultry industry may also apply to other animal units, such as swine and veal production.

Frequency

The frequency of cleaning and disinfecting (C/D) depends on economics and flock health. As long as there are no disease problems, each company follows its own schedule for C/D. It is always scheduled between flocks, when the house is empty and easiest to clean.

Most companies C/D after the productive life of each breeder or commercial egg flock (approximately once a year—longer if a flock is molted and kept for another laying cycle). Likewise, the pullet farms that supply these breeder and commercial egg farms with young sexually mature birds are generally C/D after each flock (approximately once every 18 to 20 weeks).

Broilers are usually only kept for six to seven weeks. A broiler farmer may have six different flocks in a house over the course of a year. Some cleaning is done between each flock, but a thorough C/D of a broiler house is only done about once every two to three years. The frequency will vary greatly between different companies. If there is a problem with a disease that can be eliminated by C/D the companies will respond according to the economics of the situation.

Preparation

By now you probably noticed that the terms clean and disinfect are almost always used together. That is because they are inseparable in practice. It is impossible to do an adequate job of disinfection without proper cleaning and preparation of the surface to be disinfected.

The preparation is the difficult and time-consuming part of C/D a poultry house. The actual disinfection is simple once the proper preparations have been made.

General Guidelines

- Remove all moveable equipment, tools, etc. from the house.
- Remove all feed from the bulk bins, feeder lines and feeders.
- Raise the feeders and drinkers out of the way.
- Remove all litter. Take it as far away from the poultry houses as possible.
- Scrape and sweep the sills, slats and floor, leaving clean, bare wood on the sills and slats, and a bare floor (no feathers or litter). Remove slats from the house for adequate cleaning.
- Clean all the equipment, nests and permanent structures with a high-pressure sprayer, or steam cleaner. Some of the equipment may be small enough to soak and scrub manually.
- Wash the entire house down using a high pressure sprayer and a fan nozzle. This usually takes about 500 gal. of water per house, with a quart of liquid soap or detergent added.
- Wash the sprayer tank thoroughly to remove all the detergent. Lightly spray the house with water to remove the detergent from the house surfaces.

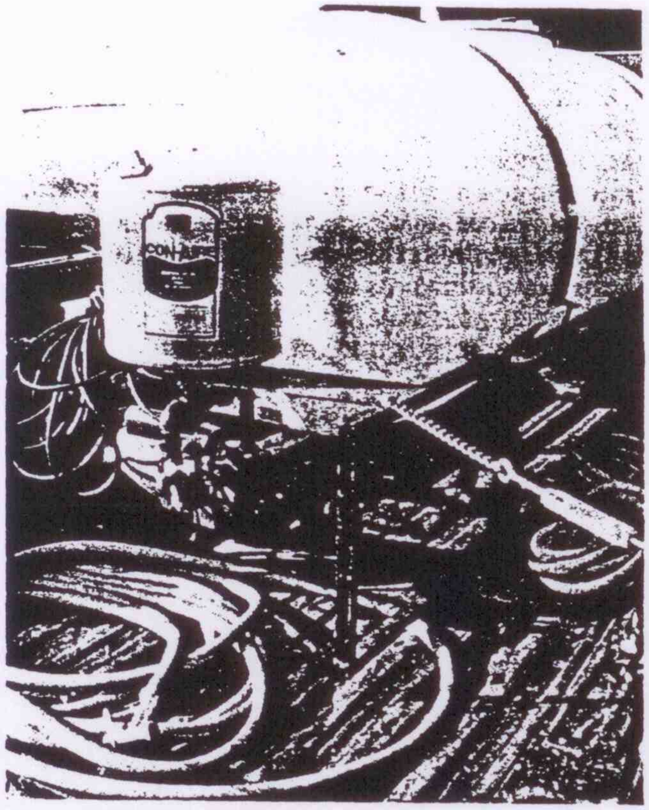

Figure 12. Portable high pressure sprayer for disinfecting poultry houses.

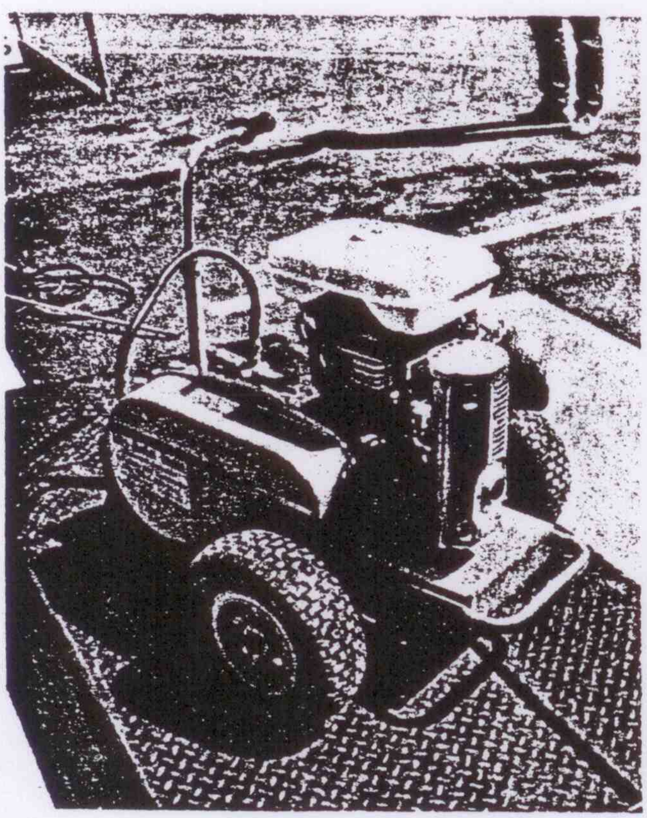

Figure 13. Portable high pressure sprayer for disinfecting poultry houses.

- Apply the disinfectant, thoroughly wetting the ceilings, side walls, and all other areas of the house. This generally takes about 100 to 150 gal., depending on the size of the house.
- Open the house to air dry, but prevent wild birds and other animals from entering. For maximum benefit, allow 10 to 15 days before placing new birds in the house. Exposure to air and the ultraviolet rays of the sun will help to eliminate some of the pathogens missed by C/D.
- Wash and disinfect your own equipment (sprayers, brushes, boots, clothing, etc.) before traveling to the next farm. This is one of the most important yet most frequently overlooked details. Do everything that you can to minimize the possibility of carrying a disease from farm to farm.

Hot water is generally preferred for cleaning and considered more effective than cold water. Orchard sprayers are usually used to deliver detergents or other cleaning agents under sufficient pressure to remove contaminating debris and to penetrate cracks and crevices. Soaps can be used with soft water, but hard water requires the use of synthetic detergents. Take care not to mix detergents. Mixing often leaves them less effective. Some disinfectants (ie. quaternary ammonium compounds) are also less effective in combination with detergents.

Disinfectants

A number of different products are available for disinfection of poultry houses. Many of these products—marketed under different trade names, contain some of the same active ingredients at the same concentrations. The label also contains some very important information for mixing and application of the disinfectant (Refer to the labels section in this publication). Always follow these instructions very carefully. Improper mixing of the compounds can result in dangerous chemical reactions and the release of deadly gases. The only way to be assured of the effectiveness of the disinfectant is to follow carefully the instructions for preparing, mixing and application.

Following is a list of the general types of compounds used for disinfection of poultry houses. Comments are made about the effectiveness of these compounds. A more detailed discussion of these compounds and the hazards associated with their use is found in the chapter on Antimicrobial Pesticides.

Disinfectants Commonly Used in Poultry Houses[1]

Quaternary Ammonium Compounds—"Quats"
—broad range of effectiveness
—fast acting, long residual action
—not effective on spores of bacteria or fungi
—problems when used with detergents or hard water

Coal Tar Distillate—cresylic acid, xylenols
—moderate range of effectiveness
—fast acting long residual action—not affected by hard water or organic matter

Iodine Compounds
—broad range of effectiveness
—fast acting, no residual action
—mildly effective against spores of bacteria and fungi
—corrosive
—inactivated by organic matter

Synthetic Phenols
—effective range varies
—fast acting, no residual action
—not greatly affected by organic matter

Chlorine Compounds
—usually hypochlorites
—broad range
—fast acting, little residual action
—not affected by hard water
—inactivated by organic matter
—not compatible with formalin fumigation

Fumigants—formaldehyde, formalin, and paraformaldehyde
—broad range of effectiveness
—rarely used in poultry houses
—more commonly used in hatcheries
—very toxic to man

As you can see, each of these have certain qualities that make them useful to the poultry industry. The most frequently used disinfectants for poultry houses are those that have a broad range of activity, residual action, and are not adversely affected by organic matter (ie. quaternary ammonium compounds and coal tar distillates).

If the reason for C/D is due to a specific disease, check with the disinfectant manufacturer or veterinarian/avian specialist to be sure that the product you are using is effective against the causative organism. In certain cases involving reportable diseases, the state and/or federal government would supervise the depopulation, cleaning, and disinfection of the farm. Contact your state veterinarian's office for a list of reportable diseases in your area.

[1]Dr. Stanley Vezey, Cooperative Extension Service, University of Georgia, Athens, GA. Circular 691, Isolation *"Sanitation and Poultry Disease Prevention."*

Hazards of Antimicrobials in Poultry Houses

Different products are available for cleaning and disinfecting poultry houses. Prior to using any of these products, carefully read the product information sheet. It should contain information on the ingredients, special precautions and first aid for accidental exposures. It is important to keep this information readily available. In an emergency you may not have time to contact the manufacturer. It is a tremendous help to the physician to know the ingredients when treating accidental exposures involving disinfectants.

Listed here are some very general hazards associated with some of the commonly used antimicrobials. Read the label and product information sheet for additional information on the specific products that you are using.

Quaternary Ammonium Compounds—These compounds can be very corrosive. Avoid contact with eyes, skin, and clothing. Wear eye protection, face shield, and rubber gloves when handling. In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes. In case of eye contact, call a physician. Remove and wash contaminated clothing before reuse.

If swallowed, drink a large quantity of milk, egg whites, gelatin solution, or water. Avoid alcohol. Call a physician immediately.

Coal Tar Distillates—Some of these products may be fatal if they are swallowed or absorbed through the skin. Avoid contact with eyes, skin, or clothing. Avoid breathing spray mist. Exposure to the skin or eyes may produce severe burns. Keep away from feed or food products.

If swallowed, call a physician or poison control center immediately. Induce vomiting if the person remains conscious. If the product is in contact with the skin, wash immediately with soap and water. Eye exposure should be followed by flushing with large amounts of water and examination by a physician.

Iodine Compounds—These compounds can be harmful or fatal if swallowed. They can cause eye damage and skin irritation. Avoid contact with eyes, skin and clothing by wearing goggles or face mask, and rubber gloves. Wash contaminated clothing before reuse.

For contact with the eyes or skin, wash immediately with plenty of water for a least 15 minutes. In case of eye exposure, call a physician. If swallowed, drink large quantities of milk, egg whites, gelatin, or water. Call a physician immediately.

Synthetic Phenols—These products may vary due to composition differences. Refer to the label or product information sheet for the specific hazards to personal safety and first aid for accidental exposure.

Chlorine Compounds—Take care not to use the hypochlorites in conjunction with other chemicals that would result in the release of free chlorine gas. Always read the labels and check with the product manufacturers before mixing disinfectants. Use chlorine products in areas with adequate ventilation.

Concentrated solutions can cause eye, skin, nose, and throat damage. For eye or skin contact, wash with plenty of water. Call a physician immediately if the solution is swallowed or if the eyes are exposed accidentally.

Fumigants—formaldehyde, formalin, and paraformaldehyde—The use of these products inside poultry houses is very rare. They are more commonly used in disinfecting equipment in hatcheries. The vapors are very irritating and will cause coughing, nausea, and vomiting. These products can cause skin and eye irritation.

If you contact any of these fumigants, remove contaminated clothing and flush the skin and eyes with plenty of water for at least 15 minutes. If the irritation persists or involves the eyes, call a physician. If swallowed, induce vomiting if the person is conscious. Then give plenty of milk or egg whites, and call a physician immediately.

Other

It should be recognized that there is a multitude of other uses of antimicrobial agents by government agencies at water and sewage treatment plants as well as by industry in food handling, product protection and preservation, paper production, metal-working lubricants, and oil drilling operations, to name a few. Since these areas of application are beyond the scope and intent of this manual, they are not discussed.

APPLICATION RATE

The amount of an antimicrobial agent to be applied per unit area or volume (such as per cubic foot, or gallons of water) is stated on the label. Too much of the agent may damage surface areas; too little may not give good control.

Figure 14. Industrial water cooling tower (Courtesy: Bonco, Jefferson, Ga.)

Many antimicrobial agents are applied by hand (such as with a mop or cloth) to a surface area. For example, the use directions may tell you to use two fluid ounces of the product per gallon of water. If you want a two-gallon mixture, how many ounces of the product would you need?

- Two ounces per gallon × two gallons = four ounces.

To find the amount needed, you must multiply the amount of the product needed per gallon times the number of gallons desired.

The use directions for an algaecide-slimicide product for a water-cooling tower (Figure 14) may tell you that three gallons of the product are needed per 10,000 gallons in the system. Your water-cooling tower contains 13,000 gallons. How much of the product do you need?

This type of problem is set up as a ratio or proportion and solved for "x".

3 : 10,000 : : x : 13,000

multiply

multiply

10,000x = 39,000 (3x13,000)
10,000x = 39,000
10X = 39
39 ÷ 10 = 3.9
x = 3.9 gallons per 13,000 gallons

In the example, 3.9 gallons of the product would be needed in a 13,000-gallon water-cooling tower.

LABELS AND LABELING

Each time you buy an antimicrobial agent, you also receive instructions that tell you how to use it. Those instructions are the labeling.

What is labeling? What is a label? These words seem alike, but they do not mean the same thing.

Labeling is all information, other than advertising, that you receive from the company or its agents about the product. Labeling includes such things as:

- The label on the product.
- Technical bulletins.
- Flyers.
- Information handed out by your dealer.

The label is the information printed on or attached to the container. This label serves many purposes:

- To the manufacturer, the label is a "license to sell."
- To the state or federal government, the label is a way to control the distribution, storage, sale, use, and disposal of the product.
- To the buyer or user, the label is the main source of facts on how to use the product correctly and legally.
- The label is a way to tell the users about special safety measures needed during use or storage and disposal of the product.

Some labels are easy to understand; others are complicated. But all labels tell you how to use the product correctly. This section will explain the items that you will find on most labels.

Parts of the Label

Product Name

Each company has names (sometimes called trade or brand names) for its products. The product name is the one used in ads. The product name shows up plainly on the front panel of the label. It is the most identifiable name for the chemical. The product name may or may not be informative of the contents or intended use of the product.

How The Product Works

Every label contains a statement that tells whether the product kills (e.g., bactericide, fungicide) or controls (e.g., bacteriostat, fungistat) the growth of microorganisms. The sample label (Figure 15) is identified as a "Disinfectant-Sanitizer-Fungicide-Deodorizer." Terms used on the label for four different levels of efficacy are: sterilant, disinfectant, limited disinfectant, and sanitizer (See "Definitions".)

Type of Formulation

Different types of formulations, such as solutions, gases, emulsions, suspensions, and solids require different handling methods. The label may tell you what type of formulation the package contains. The same antimicrobial agent may be available in more than one formulation.

Ingredient Statement

Every label must list what is in the product. This list is written so that you can see quickly what the active ingredients are. The amount of each active ingredient (the chemical that does the work) is given as a percentage by weight or as pounds per gallon of concentrate. Each active ingredient will be listed by the chemical name. A common name may also be given. The label must also show what percent of the contents is made up of inert ingredients. The inert ingredients do not have to be named. Refer to the sample label.

Net Contents

The net contents number tells you how much of the product is in the container. This can be expressed in gallons, pints, pounds, quarts, or other units of measure.

Name and Address of Manufacturer

The law requires the manufacturer or distributor of a product to put the name and address of his company on the label. This is so you will know who made or sold the product.

Registration and Establishment Numbers

The registration number shows that the product has been registered by the Environmental Protection Agency (EPA). It is usually found on the front panel of the label and is written as "EPA Registration No. 00000-00." The establishment number tells what factory made the chemical, in which state the factory is located, and the number assigned to the factory. The establishment number may be written as 000-MI-1. This number does not have to be on the label, but must be somewhere on the wrapper or outside container of the package so it can be read clearly and easily.

SAMPLE LABEL

Sanitizing of Food Processing Equipment and other Hard Surfaces in Food Contact Locations.

For sanitizing food processing equipment, dairy equipment, food utensils, dishes, silverware, glasses, sink tops, countertops, refrigerated storage and display equipment and other hard surfaces. No Potable water rinse is required.

Wash and rinse all articles thoroughly, then apply a solution of 1 oz. ____________ in 4 gallons of water.

Apply to sink tops, countertops, refrigerated storage and display equipment and other stationary hard surfaces by cloth or brush. No Potable water rinse is required.

Dishes, silverware, glasses, cooking utensils and other similar size food processing equipment can be sanitized by immersion in a 1 oz./4 gallon dilution of ____________.

No Potable water rinse is required.

At 1 oz./4 gallons, ____________ fulfills the criteria of Appendix F of the Grade "A" Pasteurized Milk Ordinances 1965 Recommendations of the U.S. Public Health Services in waters up to 1000 ppm of hardness calculated as $CaCO_3$ when evaluated by the AOAC Germicidal and Detergent Sanitizer Method against Escherichia coli and Staphylococcus aureus.

The udders, flanks, and teats of dairy cows can be sanitized by washing with a solution of 1 oz. ____________ in 4 gallons of warm water. No Potable water rinse is required.

Use a fresh towel for each cow. Avoid contamination of sanitizing solution by dirt and soil. Do not dip used towel back into sanitizing solution. When solution becomes visibly dirty, discard and provide fresh solution.

Precautionary Statements

Hazards to Humans and domestic animals

DANGER

Keep out of reach of children. Corrosive. Causes eye damage and skin irritation. Do not get in eyes, on skin, or on clothing. Protect eyes and skin when handling. Harmful if swallowed. Avoid contamination of food.

STORAGE AND DISPOSAL

- DO NOT CONTAMINATE WATER, FOOD, OR FEED BY STORAGE OR DISPOSAL
- OPEN DUMPING IS PROHIBITED
- DO NOT REUSE EMPTY CONTAINER

PESTICIDE DISPOSAL

PESTICIDE OR RINSATE THAT CANNOT BE USED OR CHEMICALLY REPROCESSED SHOULD BE DISPOSED OF IN A LANDFILL APPROVED FOR PESTICIDES OR BURIED IN A SAFE PLACE AWAY FROM WATER SUPPLIES.

CONTAINER DISPOSAL

TRIPLE RINSE (OR EQUIVALENT) AND DISPOSE IN AN INCINERATOR OR LANDFILL APPROVED FOR PESTICIDE CONTAINERS, OR BURY IN A SAFE PLACE.

GENERAL

CONSULT FEDERAL, STATE OR LOCAL DISPOSAL AUTHORITIES FOR APPROVED ALTERNATIVE PROCEDURES SUCH AS LIMITED OPEN BURNING.

____________ **DISINFECTANT-SANITIZER**

FUNGICIDE DEODORIZER

Disinfectant-Sanitizer-Fungicide Deodorizer for Hospital, Institutional, Industrial, School, Dairy and Other Farm and Home Use

AOAC Phenol Coefficients

Staphylococcus aureus, ATCC #6538	77.5
Salmonella typhosa, ATCC #6539	77.5

Active Ingredients	
Didecyl dimethyl ammonium chloride	7.5%
Isopropanol	3.0%
Inert Ingredients	89.5%
	100.0%

KEEP OUT OF REACH OF CHILDREN.

DANGER

Statement of Practical Treatment

In case of contact, immediately flush eyes or skin with plenty of water for at least 15 minutes. For eyes, call a physician. Remove and wash contaminated clothing before reuse.

If swallowed, drink promptly a large quantity of milk, egg whites, gelatin solution; or if these are not available, drink large quantities of water. Avoid alcohol. Call a physician immediately.

NOTE TO PHYSICIAN: Probable mucosal damage may contraindicate the use of gastric lavage. Measures against circulatory shock, respiratory depression, and convulsion may be needed.

SEE LEFT PANEL FOR ADDITIONAL PRECAUTIONARY STATEMENTS

EPA Registration No.

Net Contents

EPA Estab. No.

Manufactured By:

Directions for Use

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

Disinfection in Hospitals, Nursing Homes and Other Health Care Institutions.

For disinfecting floors, walls, countertops, bathing areas, lavatories, bedframes, tables, chairs, garbage pails and other hard surfaces.

Add 3½ oz. ____________ to 4 gallons water. Apply to previously cleaned hard surface with mop or cloth.

At this use-level, ____________ is effective against Pseudomonas aeruginosa.

Disinfectant in Institutions, Industry, Schools and Homes

For disinfecting floors, walls, bedframes, countertops, tables, chairs, garbage pails, bathroom fixtures and other hard surfaces.

Add 2 oz. of ____________ to 4 gallons of water. Apply to previously cleaned hard surface with mop or cloth.

At 2 oz./4 gallon use-level, ____________ is effective against Staphylococcus aureus, Salmonella choleraesuis and Trichophyton interdigitale (the athlete's foot fungus).

Disinfection of Barber Tools

Barber tools (such as combs, brushes, razors, and scissors) can be disinfected by immersing in a ½-oz./gallon solution of ____________.

Disinfection of Poultry Equipment, Animal Quarters and Kennels.

Poultry brooders, watering founts, feeding equipment and other animal quarters (such as stalls and kennel areas) can be disinfected after thorough cleaning by applying a solution of 2 oz. ____________ in 4 gallons of water with a mop, cloth or brush. Small utensils should be immersed in this solution.

Prior to disinfection, all poultry, other animals and their feeds must be removed from the premises. This includes emptying all troughs, racks and other feeding and watering appliances. Remove all litter and droppings from floors, walls and other surfaces occupied or traversed by poultry or other animals.

After disinfection, ventilate buildings, coops and other closed spaces. Do not house poultry, or other animals, or employ equipment until treatment has been absorbed, set or dried.

All treated equipment that will contact feed or drinking water must be rinsed with potable water before reuse.

Figure 15. Sample label.

Signal Words and Symbols

To do their job, antimicrobial agents must control the target pest. By their nature, they are toxic and can be hazardous to people. You can tell the toxicity of a product by reading the signal word and looking at the symbol (if there is one) on the label.

Signal words—One of the most important parts of the label is the signal word. It tells approximately how hazardous the material is to people. The signal words that follow are set by law. Antimicrobial agents that have "Danger" on the label are usually those that may cause irreversible skin and/or eye damage. Pay attention to the signal word on the label. It is there to remind you that the contents could make you sick, or even kill you. Each manufacturer must use the correct signal word on every label.

Signal Words	Toxicity
DANGER	Highly toxic
WARNING	Moderately toxic
CAUTION	Low toxicity or comparatively free from danger.

All products must bear the statement, "Keep Out of Reach of Children," unless the EPA administrator has waived this requirement for the product.

Symbol—The best way to catch a person's eye is with symbols. This is why a skull and crossbones symbol is sometimes used on highly toxic materials along with the signal word DANGER and the word POISON.

Precautionary Statements

Hazard to humans and domestic animals—This section will tell you ways in which the product may be harmful to people and animals. It also will tell you of any special steps to be taken when handling the product, such as the kind of protective equipment needed.

Environmental hazards—Antimicrobial agents are useful chemicals, but incorrect or careless use can cause undesirable effects. To help avoid this, read and follow the label containing environmental precautions.

Here are some examples:

- "Keep out of lakes, streams, or ponds."
- "Treated effluent should be discharged where it will not drain into lakes, streams, ponds, or public water."
- "Do not contaminate water by cleaning of equipment or disposal of waste."

Labels may contain broader warnings against harming birds, fish, and wildlife.

Physical and chemical hazards—This section deals with any special fire, explosion, or chemical hazards that the product may pose.

Statement of practical treatment—If exposure by swallowing or inhaling the product or getting it in your eyes or on your skin would be harmful, the label will tell you emergency first aid measures. It also will tell you what types of exposure require medical attention.

The pesticide labeling is the most important information you can take to the physician when you think someone has been harmed or poisoned by exposure to the product. Most areas have a poison control center to advise on emergency procedures. Many container labels list a number to call collect in case of an emergency endangering life or property/environment.

Statement of Use Classification

Every label will show whether the product is for general use or for restricted use. EPA puts every product use into one of these two classes. The classification is based on:

- The degree of toxicity.
- The way the antimicrobial agent is used.
- Its effect on the environment.

Restricted use—A restricted use antimicrobial agent could cause some human injury or environmental damage even when used as directed on the label. The label on these products will say:

RESTRICTED USE
PESTICIDE
For retail sale to and application only by certified applicators or persons under their direct supervision.

The restricted use statement appears at the top of the label's front panel.

General use—If an antimicrobial agent does not have the restricted use statement on the label it is intended for general use—even though the term general use is not on the label. General use antimicrobials may still have certain hazards or concerns that are addressed on the label.

Directions for Use

The instructions on how to use the antimicrobial agent are an important part of the label or labeling for you. This is the best way to find out the right way to apply the product and the correct amount of use.

The use instructions will tell you:

- The level of the product's antimicrobial activity.

- The type of microorganisms the product is registered to control. Labels use group names such as bacteria, fungi, algae, slime, and yeasts. Some labels will name the specific microorganisms to be controlled.
- Recommended use areas (such as hospitals, industry).
- The substrate (surface or material) on or in which the product can be used.
- Whether the product is for general or restricted use.
- Whether the product should be diluted, and if so, how to prepare dilutions.
- How much to use.
- Where the materials should be applied.
- When it should be applied.
- How it should be applied.
- Whether surface or objects should be precleaned before application.
- Contact/exposure time.
- Whether the product should be rinsed or removed from surfaces after use.

Misuse Statement

This section states: "It is a violation of Federal law to use a product in a manner inconsistent with its labeling."

Do not use an antimicrobial agent on or in any site or surface or article not listed on the label. Do not use it to control any group of microorganisms not related to those listed on the label. Never dilute the antimicrobial agent to form concentrations other than those specified on the label.

Before a product can be registered, EPA requires the manufacturer to conduct many tests to be sure the label directions are correct. By following them exactly, you will:

- Get the best results the product can give.
- Avoid breaking the law.
- Protect yourself.

Category of Applicator

If required for the product, this section limits use to certain categories of commercial applicators.

Storage and Disposal Directions

Store and dispose of every antimicrobial agent correctly. This section tells you how to store and dispose of the product and the empty containers.

Phenol Coefficient

The Association of Official Analytical Chemists (AOAC) phenol coefficient number appears on the label of some antimicrobial products, most commonly, disinfectants. The phenol coefficient is a ratio of the concentration of the product and the concentration of phenol required to kill certain bacteria in a specified time. It is not necessarily a good measure of the activity of the product.

Use-Dilution Method

The AOAC Use-Dilution Method or test is referred to on some labels. This laboratory test measures whether a disinfectant product kills test bacteria on a standard hard surface. Some labels list the bacteria measured in the test.

These are: *Salmonella choleraesuis, Staphylococcus aureus,* and for hospital disinfectants, *Pseudomonas aeruginosa.*

PROTECTING PEOPLE AND THE ENVIRONMENT

Protecting People

Most reported poisoning cases involving antimicrobial agents occur in the home. They often involve young children who have drunk disinfectants such as pine oil or phenols. These children cannot read and think the bottle contains something good to drink. The parents may be at fault for storing these products within reach of their children. A few adults and children have received skin and eye damage from spilled concentrates.

Use of chlorine in swimming pools has resulted in a few accidents caused by gas being inhaled from leaking tanks, gaskets, or lines.

The improper dilution of a germicidal detergent for disinfecting cribs in a hospital nursery caused about 20 infants to become sick. Someone did not read the label.

Mixing concentrated calcium hypochlorite with a quaternary ammonium compound can cause an explosion. In some cases, mixing different antimicrobials can generate toxic gases such as when chlorine gas is generated when muriatic acid is mixed with chlorine containing compounds. Do not mix different antimicrobial agents unless the label says you can.

Antimicrobial agents enter the body:

- Through the skin (dermal)—primarily from chemicals splashed on the skin.
- Through the eyes—primarily from chemicals splashed into the eye.

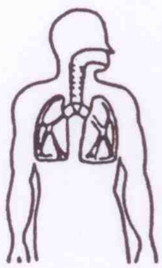

Figure 16. Respiratory route.

- Through the lungs (inhalation)—usually from accidental formation of aerosols during mixing of the chemicals, or from the gas phase of a few compounds.

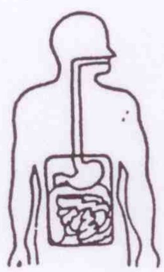

Figure 17. Oral route.

- Through the mouth (oral)—frequently from residues left on treated objects but occasionally from accidental ingestion, usually by children. Antimicrobial agents may be swallowed when in swimming pools, spas, and the like.

Acute toxicity occurs when a large quantity of an antimicrobial agent is inhaled, swallowed, or makes contact with skin or eyes over a very short time period.

Chronic toxicity is due to repeated exposures to small amounts of a chemical over a long period of time. There is little evidence that the uses of antimicrobial compounds described in this manual cause chronic toxicity. To be sure, however, follow closely label precautions on:

- Skin contact.
- Washing of hands.
- Use of gloves, masks, and other protective devices.
- Washing of work clothes.

Figure 18. Dermal route.

Symptoms of Poisoning

Know what kinds of sickness are caused by the antimicrobial agents you use. Know also the conditions under which each one may make you sick.

There are two kinds of clues to pesticide poisoning. Some are feelings that only the person who has been poisoned can notice—such as nausea or headache. These are symptoms. Others, like vomiting, also can be noticed by someone else. These are signs. So you should know:

- What your own feelings might mean.
- What signs of poisoning to look for in your co-workers and others who may have been exposed.

Antimicrobial agents in the same chemical group usually cause similar kinds of sickness. The sickness may be mild or severe, depending on the chemical and the amount absorbed. But the pattern of illness caused by one type of antimicrobial agent is usually similar. Having some of the signs and symptoms does not always mean you have been poisoned. Other kinds of sickness (such as influenza and food poisoning) may cause signs and symptoms much like those of antimicrobial poisoning. Headache and a feeling of being unwell, for example, may signal the start of many kinds of illness. The pattern of particular symptoms and signs may make it possible to tell one kind of sickness from another. Certain blood and urine tests can sometimes help distinguish poisoning caused by antimicrobial agents from other illnesses.

Direct contact with antimicrobial agents, especially concentrates, may cause severe injury to skin and eyes. Contact is usually accompanied by irritation, burning, and pain. Skin contact with some fumigants (ethylene oxide, aldehydes) can cause severe skin damage, especially if the contaminated skin is covered by clothing or gloves.

If an antimicrobial agent has been swallowed or inhaled, the first symptoms are usually gastrointestinal upset, such as nausea, vomiting, and abdominal pain. Headache and dizziness are often present. Inhalation of air containing a high concentration of chemicals such as chlorine can cause severe respiratory irritation.

If you see such signs or if you think someone has swallowed an antimicrobial agent, get medical help immediately.

First Aid

If medical help is not immediately available, follow the first aid instructions on the label. If you suspect that a person has been poisoned, do not leave him alone. Do not allow yourself or anyone else to become dangerously sick before calling a physician or going to the hospital. It is always better to be too cautious than too late. If possible, take the label from the container or the container itself when you seek medical aid. To give proper treatment, the medical personnel usually will need information about the nature of the chemical that is causing the symptoms.

Every antimicrobial agent label contains directions for first aid treatment. Study these instructions carefully before diluting the chemical or using it in any form.

If direct contact with the chemical occurs: Flush with a large amount of water to remove any dangerous concentration of the antimicrobial agent. Use soap or detergents to remove the last traces of the antimicrobial agent from the skin, only if recommended on the label.

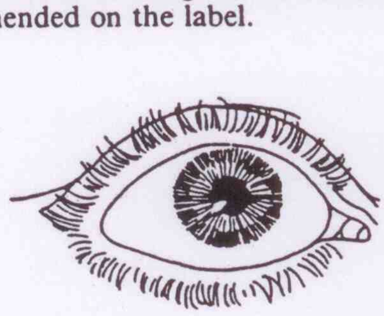

Figure 19. Eye route.

Be careful and prompt when the eye is involved. Flush the eye with plain water for 15 minutes or longer to remove harmful substances. Then get medical help.

Figure 20. Washing the eye.

If someone has inhaled an antimicrobial agent: Move the victim to fresh air as quickly as possible.

If an antimicrobial agent has been swallowed: Never induce vomiting unless the label or physician tells you to. See a physician immediately.

Protecting Your Body

Most contact with concentrated antimicrobial agents occurs on or through the skin and eyes. Instruct all users to wear clothing that guards the whole body and provides specific protection to eyes and hands. Wear goggles or a face shield to reduce chances of splashing a chemical in your face and eyes.

Even if your hands and arms are protected, wash them after mixing a chemical. Wash clothes worn while diluting concentrated chemicals after each use to avoid chemical build up in them.

Any time you spill a pesticide on yourself, wash it off immediately.

Protective Clothing and Equipment

The greatest hazard to commercial applicators using antimicrobial agents is skin and eye damage. Guard your eyes with goggles or a face shield when handling concentrated forms of toxic chemicals. Protect your hands with liquid proof gloves when mixing any toxic chemical. Wear gloves long enough to protect the wrists. Do not wear gloves lined with a fabric such as cotton. The lining is hard to clean if a chemical gets on it. Wear sleeves outside of or taped to the gloves. The hazards from skin contact are much less after the chemical is diluted.

Protective devices for the respiratory tract are not often needed with antimicrobial agents. Provide adequate ventilation or fresh air whenever an antimicrobial agent (liquid, powder, or tablets) is being diluted or mixed.

If a respirator is needed, be aware that several types are available. The chemical cartridge respirator covers the mouth and nose. Air is filtered through a filter pad and a cartridge that absorbs certain types of chemical vapors. Use this type of respirator when you are exposed to intermittent concentrations of a volatile and toxic antimicrobial agent.

The chemical canister respirator covers a larger area of the face, and has a larger and longer lasting canister than the cartridge respirator. Use this type respirator when you are exposed to a continuous concentration of a volatile and toxic chemical.

Wear a cartridge or canister approved by the National Institute of Occupational Safety and Health (NIOSH) or the Mine Safety and Health Administration (MSHA) for the specific type of chemical you are using. Remember, read the manufacturer's instructions carefully on the use and care of these respirators.

Care and Maintenance of Clothing and Equipment

Wear clean clothing daily. If clothing gets wet with a concentrate or highly toxic chemical, change clothes immediately. Do not store or wash contaminated clothing with other laundry. Wash gloves daily, inside and out, and hang them to dry. Test gloves for leaks by filling them with water and gently squeezing. Throw out damaged gloves.

Wash goggles or face shields daily. Elastic or fabric headbands often absorb chemicals and are difficult to clean. Have spare ones so you can launder or replace them often.

Follow carefully the manufacturer's instructions for the proper cleaning, storage, and maintenance of your respirator. Change cartridges or canisters often.

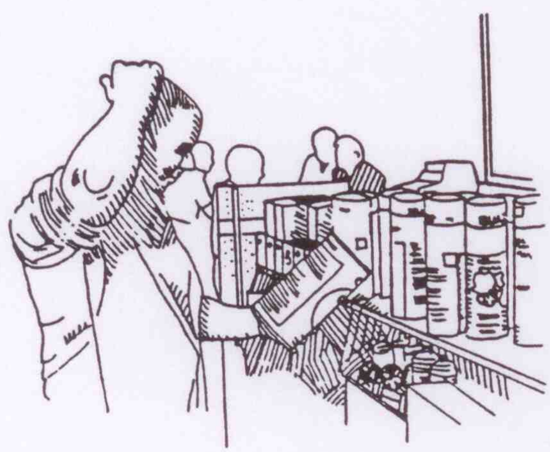

Figure 21. Read the label.

Protecting the Environment

Our environment is our surroundings, including its many forms of life. The benefits we can get from antimicrobial agents must be balanced against the harm they can do to the environment. Knowing how to use these chemicals correctly includes knowing how to minimize the pollution they may cause.

How Antimicrobial Agents Harm the Environment

Antimicrobial agents must be used correctly, according to established protocols or the manufacturer's recommendations. If not used correctly, they can:

- Harm plants.
- Leave undesirable residues.
- Damage the environment in other ways.

All antimicrobial agents adversely affect some type of microorganism. Therefore, any agent can damage the environment if not chosen, used, and disposed of with care.

Since most antimicrobial agents are used mainly indoors on specific target areas, the risk of widespread environmental contamination is less than with other types of chemicals that are applied outdoors or over wide areas.

Select the antimicrobial agent that is labeled for your specific uses.

Soil

If not disposed of correctly, antimicrobial agents can contaminate soil.

Air

The ability of an antimicrobial agent to move in air depends on the nature of the chemical, its ability to vaporize, and other factors. Antimicrobial agents that might be spread in this manner should be controlled by making sure that:

- No unnecessary amounts are carried by air currents.
- Those that are released are diluted to a level that is safe for the environment.

Water

It is impossible to totally prevent pollution of water supplies with antimicrobial agents used for washing and flushing. Be aware, however, that most fish and other aquatic life are sensitive to even slight changes in their environment. For example, 25 gallons of undiluted pine oil and sodium hydroxide used to clean one city swimming pool drained into a creek and killed about 45,000 fish. Normal use (with dilution) should not cause problems unless an unusually large amount of concentrate is washed or drained directly into waterways.

When antimicrobial agents must be disposed of in water, it is most important to dilute them adequately. Also be aware of other limits that might be required by state or local authorities. Some chemicals can be neutralized before disposal. Consult the manufacturer for the correct method.

Effluents from water cooling systems—Water that is necessarily purged or blown down from circulating water systems contains minerals and antimicrobials used for biological fouling control, as previously discussed. This water may be subsequently treated in a sewage treatment plant and rendered harmless, or it may be dumped into streams or lakes. EPA requirements prohibit the latter type of disposal without a proper permit. Such permits are issued only if the effluent blowdown water does not contain a pollutant or if the water is first treated to remove any such pollutant. Current and future concerns over the protection of our environment, and especially our water supplies, will no doubt eliminate the use of many antimicrobials which are persistant or not readily decayed or destroyed in our soils and streams.

PRECAUTIONS FOR SAFE USE OF ANTIMICROBIALS

Most parts of your job may involve some risk of illness or injury from antimicrobial agents:

- Hauling, storing, opening containers, mixing, loading, or applying antimicrobial agents.
- Repairing equipment.
- Working with antimicrobial agents in closed areas.
- Cleaning application equipment after use.
- Disposing of surplus antimicrobial agents and empty containers.
- Cleaning up spills.
- Cleaning protective clothing and equipment.

Most of these tasks are done indoors. Each requires some safety measures to prevent harm to the materials being treated, to people and animals, and to soil, air, and water outside the area of use.

To prevent harm from antimicrobial agents, follow safety precautions and use common sense. Here are the minimum safety steps you should take.

Before You Buy an Antimicrobial Agent

Select the correct antimicrobial agent. The first and most important step is to determine what type of organism(s) you wish to control. Next, determine which antimicrobial agents are registered to control the organism(s) in or on the particular material. You may have a choice of several. You may need help to guide you. Common sources of information are health agencies and officials, industrial specialists, and antimicrobial manufacturers and dealers.

At the Time of Purchase

Read the label. It is important for you to find out:

- Restrictions on use.
- If this is the correct antimicrobial agent for your problem.
- If the product can be used safely.
- Environmental precautions needed.
- If the formulation and amount of active ingredient are right for your job.
- If you have the right equipment to apply the antimicrobial agent.
- If you have the right protective clothing and equipment.
- How much of the chemical you need.
- The rate of application.
- Special instructions.
- Directions for using the product may have changed since the last time you read the label.

Transportation of Antimicrobials

You are responsible for the safe transport of your antimicrobial agents.

- Fasten down all containers to prevent breakage and spillage.
- Keep these agents away from food, feed, clothing and passengers.
- Transport antimicrobial agents in their original containers.
- Keep paper and cardboard packages dry.
- If any antimicrobial agent is spilled in or from the vehicle, clean it up right away. Use correct cleanup procedures (described later).
- Do not leave unlocked antimicrobial agents unattended. You are responsible if accidents occur.

Storage of Antimicrobials

The label will tell you how to store the product.

When antimicrobials arrive, store them in a locked and posted place. Keep them away from children and other untrained persons. Do not store antimicrobials with food, feed or drug supplies.

Choose a storage place for the antimicrobial agents that is dry, cool and out of direct sunlight. Provide enough insulation to keep the chemicals from freezing or overheating.

The storage place should have:

- Fire-resistant construction.
- Nonabsorbent flooring.
- Good ventilation.
- Good lighting.
- A lock on the door.

Keep the door locked. Store all chemicals in the original containers. Check every container often for leaks or breaks. If one is damaged, transfer the contents to a container that has held exactly the same antimicrobial agent. Clean up any spills correctly.

Keep an up-to-date inventory of the kinds and amounts of agents you have.

Mixing Antimicrobials

Keep animals and people out of the mixing area. Do not mix or load antimicrobial agents unless there is good lighting and ventilation.

Before handling an antimicrobial-agent container, put on the correct protective clothing and equipment.

Each time you use an antimicrobial agent, read the directions for mixing. Do this before you open the container. This is essential.

When taking an antimicrobial agent out of the container, keep the container and chemical below eye level. This will avoid a splash or spill on your goggles or protective clothing. Do the same thing when pouring or dumping any antimicrobial. Carefully open containers with undiluted antimicrobial agents in the form of powders to avoid exposure.

If you splash or spill a concentrated antimicrobial agent while mixing:

- Stop right away.
- Remove contaminated clothing.
- Wash body thoroughly with large amounts of water. Use soap or detergent if recommended on the label. Speed is essential.
- Put on clean clothing.
- Clean up the spill.

When mixing antimicrobial agents, measure carefully. Use only the amount called for on the label. Mix only the amount you plan to use.

To prevent spills, replace all pour caps and close containers after use.

Note: The label may warn you not to mix certain antimicrobials together or toxic gases may bc generated—such as chlorine.

Applying Antimicrobials

Read the label again to find out:

- The protective equipment and clothing needed to handle the chemical.
- The specific warnings and first aid measures.
- What it can be mixed with.
- How to mix it.
- How much to use.
- Safety measures.
- When and where to apply to control the microorganisms.
- How to apply.
- The rate of application.
- Special instructions.

Wear the correct protective clothing and equipment. Be sure pails or other measuring devices are clean and properly calibrated before using.

Before applying antimicrobial agents by spraying, be sure that all unauthorized personnel are out of the vicinity.

Cleaning Equipment

Clean mops, pails, and other gear used in applying an antimicrobial agent as soon as you finish using them. Don't forget to clean any measuring cups used in mixing the product. Clean both the inside and outside. Follow the manufacturer's directions.

Disposal

Excess Antimicrobial Agents

EPA recommends ways to dispose of excess pesticides (including antimicrobial agents). Consult local authorities (health or solid waste) for procedures in your area. If you have excess antimicrobial agents:

- Use them up as directed on the label, if possible.
- Burn them in a specially designated incinerator, if permissable.
- If you do not have access to proper facilities for burning, bury the antimicrobial agents in a specially designated landfill.
- If you can neither burn or bury them right away, store them safely until you can.

Containers

To prepare containers containing liquids for disposal:

1. Empty the container into the mixing tank or other receptacle. Let it drain an extra 30 seconds.
2. Fill it one-fifth to one-fourth full of water.
3. Replace the closure and rotate the container. Upend the container so that rinse water reaches all the side surfaces.
4. Drain the rinse water from the container into the tank. Let the container drain an extra 30 seconds after emptying.
5. Repeat steps 2 through 4 at least two more times for a total of three rinses.

Remember to empty each rinse solution into the tank.

The EPA recommendations divide containers into three groups. They tell you to dispose of each kind. Remember, containers under pressure, such as aerosol cans, will explode when heated. Observe label precautions for these special containers.

Group I containers—These are containers which will burn, and:

- Held organic or metallo-organic antimicrobial agents, but not organic mercury, lead, cadmium, or arsenic compounds.

Here are ways to dispose of them:

- Burn them in a specially designated incinerator for chemical wastes (very few are available).
- Bury them in a specially designated landfill for chemical wastes.
- Burn small numbers of them as directed by state and local regulations.

Group II containers—These are containers which will not burn, and:

- Held organic or metallo-organic chemicals, but not organic mercury, lead, cadmium, or arsenic compounds.

Here are ways to dispose of them:

- Rinse the containers three times.
- Many large containers in good shape can be reused by your supplier. Return them to your manufacturer, formulator, or drum reconditioner.
- Send or take them to a place that will recycle them as scrap metal or will dispose of them for you.
- All rinsed containers may be crushed and buried in a sanitary landfill. Follow state and local standards.

If containers have not been rinsed:

- Bury them in a special designated landfill.
- Incinerate them in a pesticide incinerator.

Group III containers—These include any containers which held organic mercury, lead, cadmium, arsenic, or inorganic pesticides.

Here are ways to dispose of them:

- Rinse them three times and bury them in a sanitary landfill.
- If they are not rinsed, enclose them in a tight outer container and bury them in a landfill specially designated for these materials.

Cleanup of Chemical Spills

Minor Spills

Always work carefully. Do not hurry.

Keep people away from spilled chemicals. Rope off the area and flag it to warn people. Do not leave unless someone is there to warn of the danger.

If the antimicrobial agent was spilled on anyone, give correct first aid according to the label instructions.

Use an absorbent material to soak up the spill. You can use soil, sawdust, cat litter, or diatomaceous earth. Shovel all contaminated material into a leakproof container for disposal. Dispose of it as you would excess antimicrobial agents in accordance with federal, state and local codes. Do not hose down the area. This spreads the chemical.

Some spills can be neutralized to stop the chemical action. Read the labeling information to make sure that you use the correct neutralizing chemical, or call the manufacturer or distributor of the antimicrobial for assistance.

Do not let anyone enter the area until the spill is all cleaned up.

Major Spills

The cleanup job may be too big for you to handle. You may not be sure of what to do. In either case, keep people away, give first aid, and confine the spill. Then call the manufacturer or CHEMTREC (The Chemical Transportation Emergency Center—A public service of the Manufacturing Chemicals Association). You can call toll-free any time at (800) 424-9300.

Report all major spills by phone to your state pesticide regulatory agency. You also may need to notify other authorities (such as state police, local sheriff, public health officials, or fish and wildlife authorities).

DEFINITIONS

Here are the definitions of terms used either in this manual or on the label to describe the chemical's purpose:

ALGAECIDE: A chemical agent that kills algae.
ANTIFOULANT: A chemical agent that prevents growth of organisms on underwater structures.
ANTIMICROBIAL AGENT/PESTICIDE: Any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest.
BACTERICIDE: A chemical agent that kills bacteria, but not ordinarily bacterial spores.
BACTERIOSTAT: A chemical agent that inhibits the growth of bacteria, without killing.
"-CIDE" or "-CIDAL": A suffix that means "to kill."
DEODORIZER: A chemical agent that prevents the formation of odors by acting upon microorganisms.
DETERGENT DISINFECTANT: A product that is both a cleaner and a disinfectant.
DISINFECTANT: A chemical product that kills microorganisms, except bacterial spores, on inanimate objects and surfaces.
DISINFECTION: A process that kills microorganisms, except bacterial spores, on inanimate objects and surfaces.
FUNGICIDE: A product that kills fungi (including yeasts).
FUNGISTAT: A product that inhibits the growth of fundi, without killing.
GERMICIDE: See "Disinfectant."
INCINERATE: Flame, burn or reduce to ashes.
LIMITED DISINFECTANT: Effective against one major group of microorganisms - such as gram positive bacteria or gram negative bacteria.
MILDEWCIDE: A chemical agent that kills mildew (a fungus that causes decay).
PHENOL COEFFICIENT: The ratio of the concentration of the product and the concentration of phenol required to kill certain bacteria in a specified time.
PRESERVATIVE: A chemical agent or process that prevents deterioration of materials.
SANITATION: The process of reducing the number of organisms to safe levels as determined by public health requirements.
SANITIZER: A chemical product that reduces microbial contaminants to safe levels as determined by public health requirements.
SLIMICIDE: A chemical preparation that prevents, inhibits, or destroys biological slimes composed of combinations of microorganisms.
SPORICIDE: A chemical agent that destroys bacterial spores as well as vegetative forms or microorganisms.
"-STAT" or "-STATIC": A suffix that means to stop growth of microorganisms without destruction.
STERILE: The condition of being free from all forms of life, especially microorganisms.
STERILIZATION: The process of effecting the complete destruction or removal of all forms of life.
STERILANT: A chemical agent intended to destroy all forms of life, including viruses, bacteria, and fungi, and their spores, on inanimate surfaces.
STERILIZER: A chemical agents or process that destroys all forms of life in or on inanimate surfaces.
USE-DILUTION METHOD: A laboratory test that measures whether or not a disinfectant product kills test bacteria on a standard hard surface.
VIRUCIDE: A chemical product that kills viruses.

ATTENTION!
PESTICIDE PRECAUTIONS

1. Observe all directions, restrictions, and precautions on pesticide labels. It is dangerous, wasteful and illegal to do otherwise.
2. Store all pesticides in original containers with labels intact and behind locked doors.
3. Use pesticides at correct dosage and interval to avoid illegal residues or injury to plants and animals.
4. Apply pesticides carefully to avoid drift.
5. Bury surplus pesticide and destroy used containers to that contamination of water and other hazards will not result.

Trade and brand names are used only for information. The Cooperative Extension Service, University of Georgia College of Agriculture does not guarantee nor warrant the standard of any product mentioned; neither does it imply approval of any product to the exclusion of others which may also be suitable.

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