Microbial Pest Control

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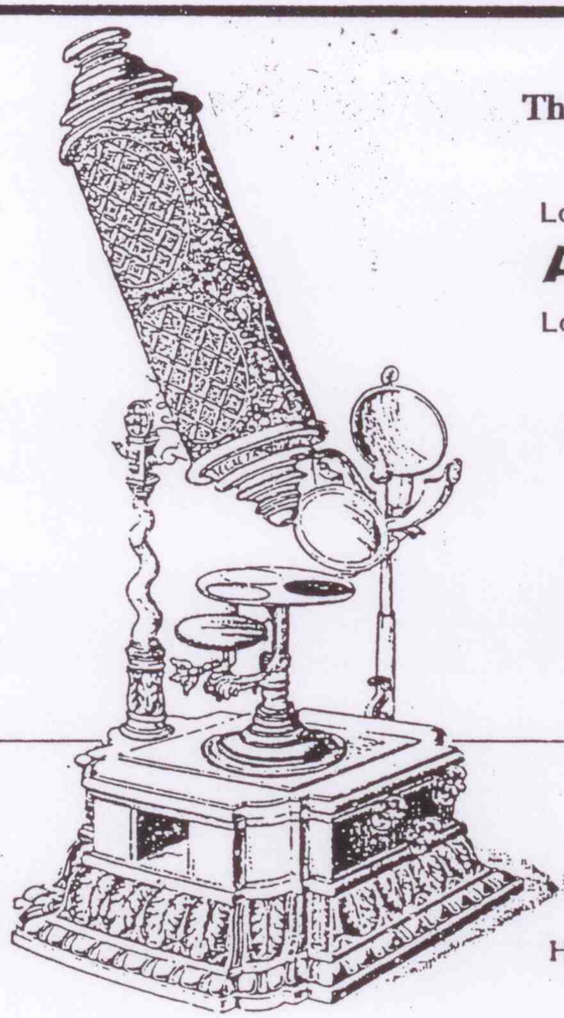

Hertel's microscope (1716)

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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).

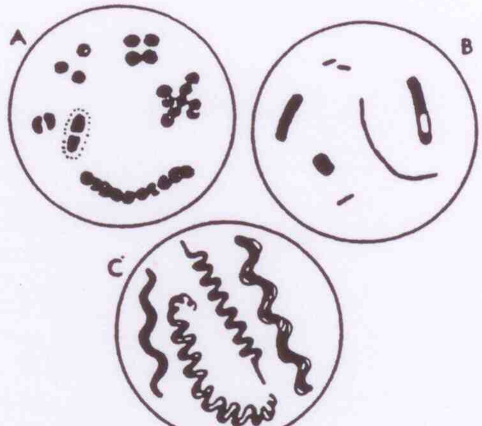

Figure 1. Shapes of bacteria. A. spherical; B. rod-shaped; C. spiral.

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.

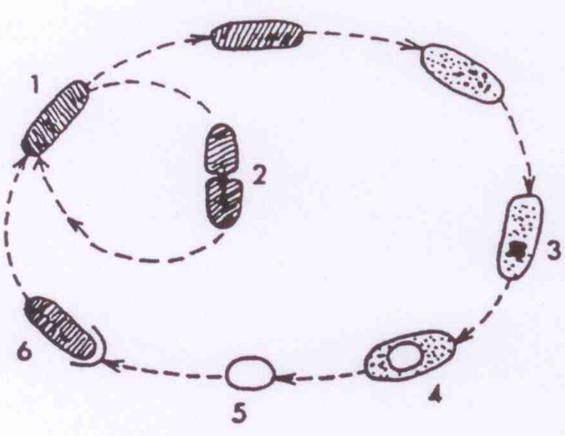

Figure 2. Life cycle of sporing bacillus. (1) Vegetative cell; (2) reproduction by fission; (3) development of prespore; (4) bacillus with endospore; (5) free spore; (6) germination of spore.

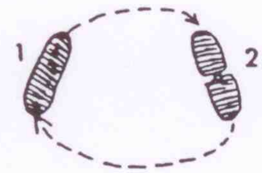

Figure 3. Life cycle of a non-sporing bacteria. (1) Vegetative cell; (2) reproduction by fission.

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

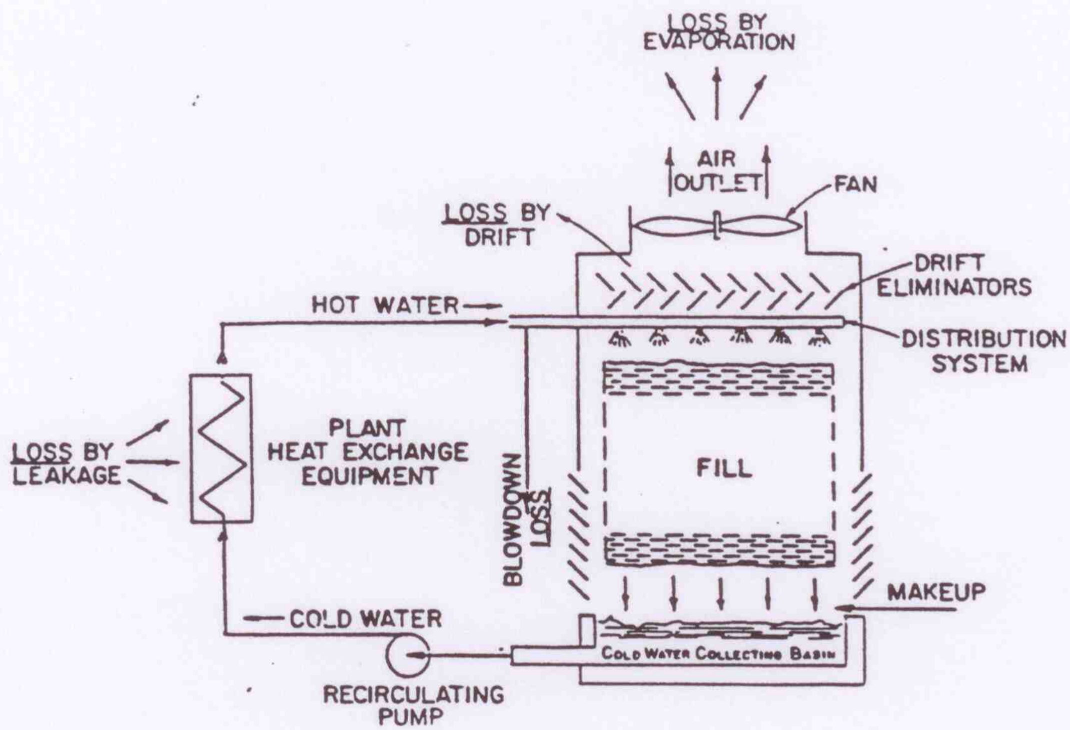

Figure 4. Typical cooling tower loop in open recirculating system with water loss areas indicated (Courtesy Buckman Laboratories, Inc.)