A COMPLETE GUIDE TO CLEANING AND SANITATION

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Beer has been brewed for thousands of years and the majority of this brewing was done before anyone knew about germs or sanitation. Sometimes the beer was good and sometimes it wasn't. Over time, brewers learned which practices seemed to make good beer, and these practices became ritual. A case in point is the historic Norwegian beer totems used in the Middle Ages. Michael Jackson reports that these sticks were passed down from generation to generation and used to stir the developing beer. The totems harbored yeast (and bacteria) of previous batches. Reusing the totems inoculated each new batch with these yeast and bacteria. Maintaining this "house yeast" was the basis for a family's brewing success. The totems were very important and were treated carefully to preserve their power for turning wort into beer.

Late in the 1860s, Louis Pasteur discovered yeast as the cause of fermentation. At about the same time he discovered that bacteria and "wild" yeasts caused the spoilage of beer (1). From Pasteur's work, it was recognized that using large amounts of healthy yeast could overcome any small amounts of bacteria present and help reduce the risk of spoilage of the final product. Once the effects of yeast and bacteria were identified, measures could be taken to control them in brewing. Unfortunately problems with beer infections persist today, particularly during the summer months when the air is teeming with bacteria and wild yeast. Only by maintaining vigilance over our sanitation techniques can we be assured of successful batches.

Sanitation is important because without it our wort, and even beer, could become infected with bacteria or wild yeast leading to off-flavors and off-aromas. Wort is an excellent source of nutrients that will support the growth of many organisms, not just yeast. Given the opportunity, any organism that ends up in the wort will begin to grow and produce metabolic byproducts that lead to any number of flavors and aromas not normally associated with beer. Thus it is very important to eliminate as many sources of potential contamination as possible. It is not possible nor is it necessary to remove every last bacterium or wild yeast that may spoil our precious homebrew. Bacteria and wild yeast are everywhere in the environment: in the air, on the kitchen counter, on the floor, on the cat or dog, on you and on all your uncleaned, unsanitized brewing equipment. By following a few simple steps to clean, then to sanitize your equipment, you can eliminate the major causes of contamination and brew beer free of off-flavors and off-aromas produced by non-brewing organisms.

DEFINING THE TERMS

Let's begin by defining some terms. Many brewers talk about sterilizing their brewing equipment when they really mean sanitizing. Unless you have an autoclave or can bake the item for an extended period of time you aren't really sterilizing. To sterilize means to eliminate all forms of life, especially microorganisms, either by chemical or physical means. None of the sanitizing agents used by homebrewers to kill microorganisms are capable of eliminating all bacterial spores and viruses. Instead of worrying about sterilization, homebrewers can be satisfied if they consistently reduce these contaminants to negligible levels.

The best a homebrewer can hope for is to clean and sanitize brewing equipment and sanitize the wort that ultimately ferments (boiling accomplishes this). Cleaning is the process of removing all the dirt and grime from the surface, thereby removing all the sites that can harbor bacteria. Cleaning is usually done with detergent and elbow grease.

When it comes to actually ridding brewing equipment and the environment around the brewery of germs, the best homebrewers can do is disinfect. More likely they will only sanitize. **In order of decreasing rank it is sterilize, disinfect, sanitize.** The term disinfect has a number of legal and regulatory definitions, but for our purposes it means to kill all the harmful microorganisms that can cause beer to spoil. A disinfectant is defined as an anti-microbial agent that is intended for application to inanimate objects or surfaces for the purpose of killing all pathogenic organisms (excluding spore-forming bacteria). To pass the official test, a disinfectant must kill the organisms in 10 minutes or less, according to the defined conditions of the appropriate test of the Association of Official Analytical Chemists (AOAC) (2). (For this discussion we will exclude the microorganisms responsible for lambic and other similar styles of beer.) The majority of chemical and physical agents homebrewers use will clean and sanitize and/or disinfect but not sterilize. But remember, sterilization is neither readily achievable nor necessary.

The most common terms used by homebrewers are sanitize and sanitizer. In general, sanitize means to use an agent to reduce the number of microorganisms to safe levels. One official definition states that a sanitizer must kill 99.999 percent of the specific test microorganism in 30 seconds (2). It is generally acknowledged that 90% of the sanitizing process is the physical cleaning of surfaces and the other 10% involves the use of a sanitizing agent (3).

The focus of this article will be interpreting these definitions as they pertain to homebrewing.

To simplify matters we will talk primarily about cleaning and sanitizing agents, how to use them and how they can affect our brewing equipment. Some of the chemical agents mentioned may also be disinfectants but we will refer to all of them as sanitizers to avoid confusion.

All sanitizers mentioned in this article are meant to be used on clean surfaces. Their ability to kill microorganisms is reduced by the presence of dirt, grime or organic material present on the surface being sanitized. These organic deposits can harbor bacteria and shield the equipment from being reached by the sanitizer. So it is up to you to make sure the surface of the item to be sanitized is as clean as possible. This may require a certain amount of scrubbing, brushing and elbow grease. but remember that a dirty surface can never be a sanitized one.

Adequately cleaning brewery materials presents another set of issues. The foremost concerns are whether or not the cleaner will have a negative effect on the life of the equipment and/or on the quality of the beer.

CLEANERS

Acetic acid, also known as white distilled vinegar, is a very effective cleaner for copper. Brewers who use immersion wort chillers are always surprised how bright and shiny the chiller is the first time it comes out of the wort. If the chiller wasn't bright and shiny when it went into the wort, guess where the grime and oxides ended up? Yes, in your beer. The oxides of copper are more readily dissolved by the mildly acidic wort than is the copper itself. By cleaning copper tubing with acetic acid once before the first use and rinsing with water immediately after each use, the copper will remain clean with no oxide or wort deposits that could harbor bacteria.

Acetic acid is available in grocery stores as white distilled vinegar at a standard concentration of 5% acetic acid by volume. It is important to use only white distilled vinegar as opposed to cider or wine vinegar because these other types may contain live acetobacteria cultures, the last thing you want in your beer! Some brewers use a number of brass fittings in conjunction with their wort chillers or other brewing equipment and are concerned about the lead that is present in brass alloys. A solution of two parts white vinegar to one part hydrogen peroxide will remove tarnish and surface lead from brass parts soaked for 15 minutes at room temperature. The brass will turn a buttery yellow color as it is cleaned. If the solution starts to turn green, then the parts have been soaking too long and the copper in the brass is beginning to dissolve.

Chlorine, commonly available as bleach, is an effective cleaner because, when dissolved in cold water, it forms a caustic solution that is good at breaking up organic compounds. Grungy deposits in old beer bottles can be effectively removed by soaking in a bleach solution for a couple of days. Bleach contains an aqueous equilibrium of chlorine. chlorides and hypochlorites. These chemical species all contribute to bleach's bactericidal and cleaning powers, but these agents are also corrosive to a number of metals used in brewery equipment. If bleach is going to be used to clean a metallic surface, care should be taken to minimize the contact time and rinse the surface thoroughly so that corrosion will not occur.

Copper is sensitive to oxidation. **Oxidizers like bleach and hydrogen peroxide** will quickly cause copper and brass to blacken as oxides form. These oxides will rub off, exposing new metal to corrosion. Cleaning and sanitizing copper wort chillers with bleach solutions is not recommended. If the acidic wort is run through a chiller that was cleaned or sanitized with bleach, the black oxides would quickly dissolve into the wort, possibly exposing yeast to unhealthy levels of copper during fermentation.

Aluminum also is attacked by caustic solutions, and the protective surface oxides will be dissolved into the solution. Brewers using aluminum brewpots in areas of alkaline water may experience a metallic taste from the aluminum in their beer; however, this detectable level of aluminum is not hazardous. There is more aluminum in a common antacid tablet than would be present in a batch of beer made in an aluminum pot with alkaline water.

As in aluminum, the corrosion inhibitor in stainless steel is the passive oxide layer that protects the surface. The 300-series alloys commonly used in the brewing industry are very corrosion-resistant to most chemicals. Unfortunately, chlorine is one of the few chemicals to which these steels are not resistant. The chlorine in bleach acts to destabilize the passive oxide layer on steel, creating corrosion pits. This type of attack Is accelerated by localization and is generally known as crevice or pitting corrosion.

Many brewers have experienced pinholes in stainless-steel vessels that have been filled with a bleach-water solution and left to soak for several days. On a microscopic scale, a scratch or crevice from a gasket can present a localized area where the surface oxide can be destabilized by the chlorine. The chlorides can combine with the oxygen, both in the water and on the steel surface, to form chlorite ions, depleting that local area of protection. If the bleach water is not circulating, the crevice becomes a tiny, highly active site relative to the more passive stainless steel around it and corrodes. The same thing can happen at the liquid surface if the keg is only half full of bleach solution. A dry stable area above, a less stable but very large area below, and the crevice corrosion occurs at the waterline. Usually this type of corrosion will manifest as pitting or pinholes because of the accelerating effect of localization.

A third way chlorides can corrode stainless steel is by concentration. This mode is very similar to the crevice mode described above. By allowing chlorinated water to evaporate and dry on a steel surface, those chlorides become concentrated and destabilize the surface oxides at that site. The next time the surface is wetted, the oxides will quickly dissolve, creating a shallow pit. When the keg is allowed to dry, that pit probably will be one of the last sites to evaporate, causing chloride concentration again. At some point in the cleaning life of the keg, that site will become deep enough for crevice corrosion to take over and the pit to corrode through.

There are a few simple guidelines to keep in mind when using chlorine with stainless steel and other metals.

1) Do not leave the metal in contact with chlorinated water for extended periods of time (no more than a few hours).

2) Use buffered/ inhibited cleaning solutions that reduce the amount of corrosion attack on the metal. Buffered and/or inhibited solutions contain salts that maintain a nominal pH or silicates that inhibit metal corrosion.

3) Fill vessels completely so corrosion does not occur at the waterline.

4) Circulate or stir the water to eliminate local concentration/deoxidation.

5) After the cleaning or sanitizing treatment, rinse the item with deionized water to prevent evaporation concentration and either dry the item completely or fill it with beer.

DETERGENTS

Household cleaning products such as dish or laundry detergents and cleansers should be used with caution when cleaning organic deposits from brewing equipment. These products often contain perfumes that can be adsorbed onto plastic equipment and manifest in the beer. In addition, some detergents and cleansers cannot be rinsed completely and often leave behind a soapy film that also can be tasted in the beer. Several rinses with hot water may be necessary to remove all traces of the detergent. There are laboratory detergents such as Alconox that can be rinsed clean when used as directed. Detergents containing phosphates generally rinse more easily than those without, but because phosphates are regarded as pollutants to the environment, they are slowly being phased out.

A case in point is **trisodium phosphate (TSP) and chlorinated (CTSP)**. TSP is a very effective cleaner for organic brewing deposits and the chlorinated form provides a sanitizing capability. TSP and CTSP are becoming harder to find, but are still available at hardware stores in the paint section. (Painters use it for washing walls because it can be rinsed away completely.) The recommended usage is one tablespoon per gallon of hot water. Solutions of TSP and CTSP should not be left to soak for more than an hour because a white mineral film can deposit on glass and metal which requires an acid solution to remove. In an experiment done with technical-grade (greater than 95% pure) TSP, a one molar solution (about two ounces in a quart) left no film on Pyrex[a], regular glass or polypropylene after 24 hours.

Automatic Dishwashers

Using dishwashers to clean equipment and bottles is a popular idea among homebrewers, but there are a few limitations. First, the narrow openings of hoses, racking canes and bottles usually prevent the water jets and detergent from effectively cleaning inside. Second, if detergent does get inside these items, there is no guarantee that it will get rinsed out again. Third, dishwasher drying additives (Jet Dry[a], for example) work by putting a chemical film on the items that allows them to be fully wetted by the water, thus preventing spots. The film can ruin the head retention of beer put into these washed items. The wetting action destabilizes the proteins that form the bubbles. It is best to use automatic dishwashers only for heat sanitizing, not cleaning. The use of dishwashers for heat sanitizing will be discussed in the next section.

Sodium Hydroxide

Commonly known as lye, **sodium hydroxide** (NaOH) and sometimes **potassium hydroxide** (KOH) is the caustic main ingredient of most heavy-duty cleaners like oven and drain cleaner. In its pure form, sodium hydroxide is very hazardous to skin and should only be used when wearing rubber gloves and goggle-type eye protection. Vinegar is useful for neutralizing sodium hydroxide that gets on your skin, but if sodium hydroxide gets in your eyes it could cause severe burns or blindness. Oven cleaner is an adequate substitute for any case that calls for sodium hydroxide. Brewers often scorch the bottoms of their brewpots, resulting in a black, burned wort area that is difficult to remove for fear of scouring a hole in the pot. The easiest solution is to apply a common brand of spray-on oven cleaner and allow it to dissolve the stain. After the burned-on area has been removed, it is important to thoroughly rinse the area of any residue from the oven cleaner. Because oven cleaners are caustic, rinsing with vinegar, a mild acid, will neutralize any remaining cleaner. Then a little detergent and water will suffice to remove any traces of the vinegar. Rinsing with vinegar is not usually necessary. It depends on the size of the stain and the amount of cleaner you use.

Sodium hydroxide is very corrosive to aluminum and brass. Copper is generally resistant to sodium hydroxide and stainless steel is only negatively affected by boiling hot solutions of sodium hydroxide (not recommended). Strong unbuffered solutions of NaOH should not be used to clean aluminum brewpots because the high pH causes the dissolution of the protective oxides, and a subsequent batch of beer might have a metallic taste.

Percarbonates

Both B-Brite[a] and One-Step[a] contain percarbonates, which is **sodium carbonate complexed with hydrogen peroxide**. There is no data available on the chemical composition of these products and how the composition affects the antimicrobial properties of the percarbonate. These products are approved as cleaners in food-manufacturing facilities. The hydrogen peroxide does provide some degree of sanitization, but it is better to rely on it only as a cleaner. B-Brite and One-Step effectively remove organic deposits from all types of brewery equipment. They will not harm plastics or metals, but the solution should not be left in contact with dissimilar metals (ex. aluminum against stainless steel) for more than a day because corrosion could occur. Use these cleaners according to the manufacturer's instructions, but generally use one tablespoon per gallon and rinse after cleaning.

SANITIZERS

Once you have selected the appropriate cleaner and scrubbed all the grime off of your equipment, it is time to sanitize the parts of your brewery that will come in contact with wort after the boil. There are several sanitizing agents available to the homebrewer and they can be used in a variety of situations.

Alcohol

The most commonly available alcohols that can be used for sanitizing are methyl, ethyl, and isopropyl. Alcohol's mechanism of action is still unconfirmed, but theories for how alcohol might kill cells include denaturing of cell proteins, interfering with cellular metabolism and destroying cell membranes. In the absence of water, proteins are not denatured as readily by alcohol, and this explains why a solution of 70% alcohol and 30% water is a better sanitizer than 100% alcohol. Alcohol will kill most bacterial organisms in less than five minutes, but because some organisms may take longer, it is best to let items soak at least 10 minutes to kill the majority present. Alcohol does not kill bacterial spores, and viruses are only killed after exposure of an hour or more, but these microorganisms are not a concern to brewers. As with all sanitizers, the degree of effectiveness is dependent on the initial cleanliness of the surface.

Alcohol as a sanitizer has limited uses in brewing. A major limitation is that all types of alcohol are reasonably flammable even at a 70 percent solution. Isopropyl and methyl alcohol are much more toxic if consumed than is ethyl alcohol, and are undesirable in finished beer because of this, let alone their undesirable flavor. Isopropyl alcohol is the most effective sanitizer of the commonly available alcohols, with ethyl alcohol being a close second. Methyl alcohol is not a very effective agent compared to the other two and this fact, combined with its toxicity, means it is not often used as a sanitizing agent (4,5). For these reasons, ethyl alcohol is the more favored alcohol for sanitization, but is rather expensive because concentrated forms are highly taxed.

Alcohol is useful for sanitizing equipment and surfaces used in yeast culturing and propagation. Isopropyl alcohol at a concentration of 70% is an excellent, inexpensive choice for sanitizing work surfaces, bottle and flask necks, instruments and your hands. The alcohol can be applied to surfaces in a number of ways, the easiest being with a small spray bottle. A piece of gauze or cotton soaked in alcohol can be used to wipe down surfaces such as tables and container openings, or instruments can be soaked in alcohol until needed. Alcohol such as isopropyl and ethyl are safe to use on most surfaces. Don't use alcohol to sanitize tubing because it can dissolve the plastic to some degree. Some plastics, such as HDPE, are generally resistant to alcohol. Metals and glass also are unaffected.

It is often stated in homebrewing lore that you can simply gargle with vodka or some other high-proof alcoholic beverage and then use your mouth to start a siphon without fear of contamination. But based on the effectiveness of alcohol, this does not seem to be such a wise idea. First of all, alcohol's ability to kill bacteria, i.e., denature proteins, is constrained by the total amount of organic material present, which for the average mouth is a fair amount depending on when the last meal was consumed. Second, an 80-proof beverage such as vodka is only 40% alcohol and most organisms are not killed in less than five minutes at this concentration. For this method to be effective, you would have to gargle with 120-proof rum or something of equal strength for 10 to 15 minutes, by which time you probably would have forgotten about brewing. Rather than risk contamination, use a small tube that fits into the end of the racking hose and suck on that to start the siphon. Once the siphon starts, remove the small piece of tubing before the wort reaches it and you don't risk contamination.

Iodine

Iodine by itself is a very good sanitizer, but it stains almost everything and is irritating to skin and other tissues. Solutions of iodine complexed with a high molecular weight carrier are more commonly used today and are called iodophors. The high molecular weight carrier is typically a polymer which is simply a molecule made up of a large number of atoms with a repeating structure. The complexing of the iodine with the polymeric carrier serves three basic functions. First, the solubility of the iodine is increased. Elemental iodine has limited solubility and combining it with a polymeric molecule greatly improves this. Second, the iodine-carrier complex provides a sustained-release reservoir of iodine because the iodine stays bound to the carrier until the free iodine concentration in solution falls below an equilibrium level. And finally, the equilibrium between the free form and the complexed form keeps the amount of free iodine low, yet at a level that kills microorganisms. Thus, the otherwise highly toxic iodine can be used safely in food and beverage applications.

Iodine can enter a microorganism fairly easily. Once it does, it kills the cell via a number of possible mechanisms. It is generally accepted that the most significant reaction involves the oxidation of the sulfur-hydrogen groups in the amino acid cysteine. Once this occurs the microorganism can no longer synthesize proteins and it dies. Other mechanisms for the disinfectant properties of iodine have been proposed but need not be discussed here (6). Suffice it to say that iodine is a very effective sanitizing agent. Data indicate a 10-minute exposure at 15 parts per million (ppm) will kill 99.999 percent of the microorganisms that cause contamination in the homebrewing environment (6).

All iodophors are produced by what is called a "cold process," meaning it uses no external heating. This process occurs in an acidic environment and the final complex in pure form has a pH of about 3, depending on the carrier used. Some formulations contain added phosphoric acid. These are primarily made for the dairy industry where the additional acid helps dissolve calcium deposits on surfaces from milk. The formulations made for the food and beverage industry, and what you are most likely to find in your homebrew shop, do not contain any added acid. This is desirable because they are safer to handle than the acid-containing formulations. You may encounter the formulation made with acid if you purchase iodophor at a dairy industry supply store. Iodophors are sold as a concentrate that is diluted to a working concentration in water. The label gives directions on how to dilute the iodophor to achieve an available iodine concentration of 12.5 ppm. Soaking equipment for 10 minutes in a solution of 12.5 ppm of available iodine is all that is needed to kill the majority of microorganisms that occur in the brewing environment. At 12.5 ppm the solution has a faint brown color that you can use to monitor the solution's viability. If the solution loses its color it no longer contains enough free iodine to kill microorganisms.

When iodophor is diluted in cold water an equilibrium is reached between the free (measurable) and bound forms. The chemistry of this equilibrium is quite complex and is not relevant to our discussion. Those of you who are interested in more details should consult reference (6). What the chemistry boils down to is this: as iodophor is added to a water solution, the free iodine in the solution reaches a maximum amount and then actually begins to drop off. WestAgro Inc. of Kansas City, Missouri, the manufacturer of the iodophor complex used in several commercial iodophor products, says the maximum amount of free iodine (that which kills microorganisms) that can be achieved in a water solution is 75 ppm. There is no advantage to using more than the specified amount. In addition to wasting the product, you risk exposing yourself and your beer to excessive amounts of iodine. In this case, more is not better. Another important point is the action of iodophor is inhibited if the pH is outside the range of 3 - 6. Achieving this range is not usually a problem because of the acidic nature of the iodophor complex. If you live in an area with high pH water (greater than 9) you should check the pH of your diluted iodophor and make adjustments with citric or phosphoric acid. Acidify your water below a pH of 9 then add the appropriate amount of iodophor. One iodophor manufacturer we spoke to recalled only one instance where an industrial user had this problem, so it should not be a major issue for homebrewers.

Make only as much iodophor sanitizing solution as you need for each use. Iodine is volatile and will outgas from the solution with time, losing its sanitizing ability. You may have noticed that an iodine solution left in an open glass jar will lose its brown color. If you do have leftover solution, store it in a tightly sealed glass jar or a PET plastic soda bottle. Solution stored this way is stable for about a week. Do not store the solution in other types of plastics because they will either absorb the iodine fairly quickly or allow it to volatize because of their gas permeability, again causing a loss of sanitizing ability. Iodophors, like other sanitizers, are most effective when used on clean surfaces. Proteins and other organic substances will bind the iodine making it unavailable for sanitizing purposes. Sulfur-containing compounds in particular are efficient iodophor inactivators.

Heat

Heat represents one of the few means by which the homebrewer can actually sterilize an item. When a microorganism is heated at a high enough temperature for a long enough time period it is killed. Both dry and wet heat are used to kill microorganisms.

Dry Heat

Dry heat is less effective than wet or moist heat in killing microorganisms, but it can still be used. The best place to do dry heat sterilization is, of course, in your oven. For an item to be sterilized by dry heat it needs to be heated at a given temperature for a given time as shown below:

DRY HEAT STERILIZATION

Temperature	Duration
338°F (110°C)	60 minutes
320°F (160°C)	120 minutes
302°F (150°C)	150 minutes
284°F (140°C)	180 minutes
250°F (121°C)	12 hours (Overnight)

The times indicated begin when the item has reached the indicated temperature. Though the duration's seem long, remember this process renders the item sterile, not just sanitized. Items to be sterilized need to be heat proof at the given temperatures. Glass and metal items are prime candidates for heat sterilization. Consider heat sterilizing flasks, tubes and petri dishes for use in yeast culturing. Some homebrewers bake their bottles using this method and thus always have a supply of clean sterile bottles. The opening of bottle or flask can be covered with a piece of foil prior to heating to prevent contamination after cooling and during storage. Other pieces of equipment should be wrapped completely in foil for best results. They will remain sterile indefinitely if kept wrapped. One note of caution: bottles made of soda lime glass are much more susceptible to thermal shock and breakage than those made of borosilicate glass and should be heated and cooled slowly. You can assume all beer bottles are made of soda lime glass and that any glassware that says Pyrex[a] or Kimax[a]' is made of borosilicate.

Moist Heat

Typically when we talk about using moist heat we are referring to the use of an autoclave or pressure cooker. These devices use steam under pressure to kill all microorganisms. Because wet heat and pressure provide a more effective heat transfer mechanism, the cycle time for such devices is much shorter than when using dry heat. The typical amount of time it takes to sterilize a piece of equipment or solution is 20 minutes at 257° F (125° C) at 20 pounds per square inch (psi). A pressure cooker is excellent for sterilizing starter solutions, glass, and certain plasticware, and for preparing agar slants for yeast culturing. Because a pressure cooker operates at high temperatures and pressures it is important that you to follow the manufacturer's directions carefully.

A pressure cooker can be used to sterilize most any heat resistant item including objects made of heat resistant glass, metal, polypropylene and polycarbonate plastics. Another form of moist heat that can be used to sanitize, as opposed to sterilize, is the heat-drying cycle of an automatic dish washer. By loading pre-cleaned bottles or equipment, and not using any! detergent or rinse agent, the steam from the drying cycle will effectively sanitize even interior surfaces. Run the equipment through the full wash cycle including heat drying. As an added bonus, the dishwasher door makes an ideal bottle-filling platform.

Chlorine
Chlorine is by far the least expensive and most widely available chemical disinfectant and sanitizer a homebrewer can use. It is available in the form of household bleach which is a 5.25% solution of **sodium hypochlorite** (NaOCI). This economical form of chlorine has the advantages of being a powerful germicide, colorless and nonstaining (except to clothes) nonpoisonous when diluted properly and a deodorizer. Because of the widespread use of bleach, it is the standard to which other sanitizers are compared. For sanitizing purposes, a concentration of 100 to 200 ppm available chlorine is needed to kill most microorganisms with an exposure time of 10 minutes. It is the available chlorine that does the killing. Use one-half ounce (one tablespoon) of bleach in one gallon of water to get 200 ppm of available chlorine, according to the Clorox Co. in Oakland, Calif., assuming you have household bleach containing 5.25%t sodium hypochlorite, as indicated on the label. The items to be sanitized should be allowed to soak for 10 minutes and then drip dried or rinsed to eliminate the majority of residual chlorine.

When **sodium hypochlorite is dissolved in cold water it reacts to form hypochlorous acid**, which is a very strong oxidizing agent. It is this compound that actually does the sanitizing in solution. Precisely how hypochlorous acid kills microorganisms has not been conclusively proven with experiments. Advanced theories revolve around the view that chlorine may inhibit important enzymatic reactions in microorganisms that are necessary for life (7, 8). Chlorine reacts rapidly with organic materials and when it does, it can no longer act as a sanitizer. This high reactivity means that your equipment needs to be free of all dirt and residues prior to being sanitized with chlorine. Because of chlorine's high reactivity, it can combine with phenolic compounds found in wort or beer and form the dreaded chlorophenols that lead to medicinal off-flavors in the finished product. To combat this problem, start by using the proper amount of bleach (one-half ounce per gallon of water), and either allow your equipment to drip dry completely or rinse with pre-boiled water prior to use.

Bleach and bleach solutions degrade over time. Generally, a fresh batch of sanitizing solution should be prepared each time it is needed. If you don't know the age of your bleach, you may want to get a chlorine test kit from a homebrew supply shop or swimming pool supplier to make sure you are in the right concentration range. If your water has a pH of 9 or greater you should check the chlorine level of the solution. A high pH inhibits the sanitizing ability of sodium hypochlorite, requiring longer exposure times to kill microorganisms. If the pH is greater than 9, follow the instructions in the iodine section for adjusting water pH. The majority of chemical sanitizing agents are more effective at higher temperatures. Microorganisms will be killed faster by a room temperature (68° F or 20° C) sanitizing solution than a 40° F (4° C) solution. The exposure times presented in this article are on the conservative side to account for variations in tap water temperatures. For best results use the recommended exposure time and concentration indicated in the Summary Table.

Microwaves
We were able to find some data indicating that microwave ovens can be used to disinfect solutions. These data demonstrate that small volumes (milliliters) of bacterial cultures could be decontaminated using a microwave oven (9). The data do suggest that a microwave can be used to heat solutions to the point of sterility. These data are based on the fact that a very heat-resistant form of bacteria could be killed when boiled in the media in which it was grown using a microwave oven. Microwaves kill by heating the water molecules present in a microorganism. When the water boils, the internal structure of the microorganism is destroyed. Because microwaves heat only water, they cannot be used to sterilize dry material.

There are microwave pressure cookers available that can be used to sterilize agar in tubes. These microwave versions of pressure cookers tend to be too small for preparing large amounts of fluids.

Hydrogen Peroxide
Hydrogen peroxide is considered a safe and effective sanitizer. It kills microorganisms by oxidizing them,

which can be best described as a controlled burning process. When hydrogen peroxide reacts with organic material it breaks down into oxygen and water. This inactivation can occur when hydrogen peroxide reacts with microorganisms, proteins or other organic residues. Hydrogen peroxide is active against a wide range of microorganisms, provided it is used full strength right from the bottle. It is active at lower concentrations but exposure times on the order of 30 to 60 minutes are required. The 3% solution sold in most drugstores is adequate to kill bacteria of most types in about 10 minutes. Because of its high cost, hydrogen peroxide has limited applications for homebrewing. It is probably best suited for disinfecting surfaces that you do not want to expose to alcohol or other sanitizers in yeast culturing. Simply pour it onto the surface or wipe it on with a piece of cotton or gauze. Or, if you need to rinse after using other sanitizers, then hydrogen peroxide is a good choice for a rinsing substance. As with other chemical sanitizers, hydrogen peroxide is inactivated when used on dirty surfaces, so make sure you use it on clean equipment.

TO RINSE OR NOT TO RINSE

When the chemical sanitizers mentioned in this article are used at the recommended concentration they do not need to be rinsed off prior to using the equipment. Brewing equipment does not even need to be allowed to drip dry if the stated concentrations are used. Simply allow the majority to drain off and then use the sanitized items. If you still feel the need to rinse, then go ahead if it makes you feel better, but use either preboiled water or some no-name beer in a can. (Beer produced by some of America's larger brewing companies is packaged using sterile filling techniques and is pasteurized. Clean and sanitize the can tops before pouring beer as a rinse solution.)

Tap water is not an acceptable solution for rinsing because it contains bacteria. In fact, the practice of rinsing with tap water negates any prior sanitation measures. Hot water in most homes is not hot enough to guarantee sanitization of the pipes between the water heater and the faucet. There are likely to be several areas where conditions are right for minimal levels of microorganisms to grow. These levels are not dangerous, but they can result in a spoiled batch of beer. To be safe, always boil the water with which you intend to rinse. The variety of cleaning and disinfecting methods available to today's homebrewer can ensure complete sanitization at every step of the brewing process. The most common sanitizing agents available are chlorine bleach and iodophor. These are the easiest to use and are effective on all brewing equipment. Sanitizing bottles can be better accomplished using heat, either in your oven or dishwasher. We hope the other methods presented here have given you options that can help in your particular home brewery. A good understanding of the various sanitation methods should save you a lot of time and frustration in your pursuit of the perfect batch.

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