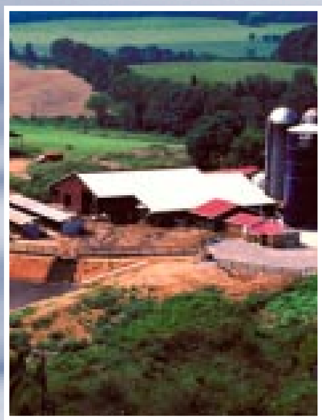

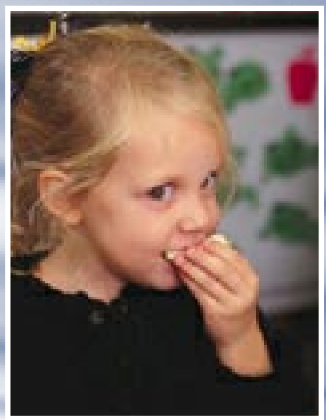

Chlorine and Food Safety White Paper

Chlorine Chemistry Council

http://c3.org

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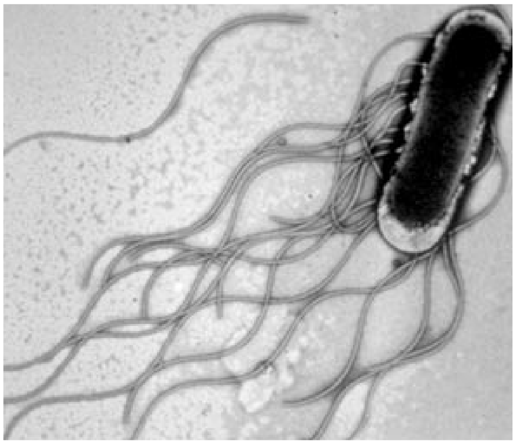
Preface

"…illness due to contaminated food is perhaps the most widespread health problem in the contemporary world and an important cause of reduced economic productivity."

—Expert Committee on Food Safety convened by the World Health Organization and the Food and Agriculture Organization of the United Nations, 1983

This paper explores the role chlorine plays in the efforts of industry, public health officials and consumers to maintain the safety of the global food supply. Chlorine and chlorine-containing compounds are critical factors in food safety all along the path leading from the farm to the consumer's plate.



Executive Summary

Chlorine plays a vital role in the safe production, processing, transport and preparation of foods of all varieties. “To date, no other sanitizing agent has appeared which competes with chlorine in all the areas needed for safe food production” (McLaren, 2000). On the farm, chlorinated water is used for irrigation and livestock watering to lower the risk of contamination of crops and livestock. Chlorine solutions are used industrially to wash and sort fruits and vegetables. The dairy, poultry, egg and meat industries use the chemical in numerous ways to prevent contamination that could lead to foodborne illness. Chlorine is used extensively in food processing and transport to disinfect surfaces of all types (e.g., work surfaces, instruments, machinery, containers) that contact edible products. In the effort to increase food safety, researchers continue to find innovative uses for chlorine as food travels from “the farm to the fork.”

The challenges of safe food production and delivery in the 21st century are unique in human history. Opportunities for food contamination are many. Some of these opportunities arise from human negligence or ignorance of hygiene. In other cases they are a consequence of modern agricultural practices, food handling techniques, changing patterns of food distribution or changing consumer preferences and demographics.

Foodborne illnesses affect millions in the United States annually.

In this era of global trade, paths from the farm to the fork have lengthened. Modern consumers demand year-round fresh fruits and vegetables of a wide variety, with fewer preservatives (Zink, 1997). This demand fuels the importation of produce from countries with variable food safety standards. It is true that, “in a globalized world, we all swim in a single microbial sea” (Brundtland, 2001).

As a result of changing demographics (e.g., the aging “Baby Boomers”) and better health care, the elderly population is growing. Advances in medicine are also prolonging the lives of the immunocompromised. These populations are statistically more vulnerable to foodborne illness. In addition, increasing numbers of US residents eat restaurant-prepared foods, rendering themselves dependent on the food handling and preparation procedures followed by these establishments.

The US Food and Drug Administration recently announced a program designed to establish a national baseline on the occurrence of foodborne disease risk factors within the retail segment of the food industry. Risk factors outlined are: food from unsafe sources; inadequate cooking; improper holding temperature; contaminated equipment and poor personal hygiene (US FDA, 2000). Combating foodborne diseases requires the constant vigilance of many segments of society and their awareness of the changing nature of the challenge. In response to recent concerns about

potential terrorist threats, US officials are calling for a stronger public health infrastructure to respond effectively to public health emergencies of all types, including those related to contamination of the food supply. This effort may provide better links among local, state, regional and national public health offices, and improve notification and response regarding foodborne disease outbreaks.

Although the US food supply is among the safest in the world, foodborne illnesses affect millions in the United States annually, causing thousands to die. Accompanying the many conveniences of modern life is an unfortunate sense of complacency about food safety on the part of many consumers. Opportunities for food contamination and cross-contamination abound in home kitchens when consumers fail to practice safe food preparation and handling.

In the developing world, foodborne disease is a major cause of infant and childhood mortality. According to the World Health Organization, children under the age of five suffer approximately 1.5 billion cases of diarrhea annually, resulting in over 3 million deaths (WHO, 1997). A significant proportion of diarrheal diseases are of foodborne origin. (Untreated or inadequately disinfected drinking water also accounts for a large proportion of diarrheal diseases.) Two to three percent of non-fatal foodborne diseases in developing countries result in long-term health consequences. The economic costs of foodborne diseases are huge and include treatment and case investigation costs, work absence and lost human potential. Chlorine is a highly effective yet inexpensive weapon available to control foodborne disease all over the world.

There are common foodborne pathogens, but the foodborne “enemy” is not static. Microorganisms harbored in foods evolve and new ones emerge. These may spread rapidly over great distances by food transportation mechanisms. Surveillance of foodborne pathogens by government and public health monitoring of outbreaks, once a relatively simple task, is now highly complex as people travel widely and food is shipped globally. Nevertheless, new technologies afford sensitive tracking techniques and rapid global electronic reporting.

Introduction

Impacts of Foodborne Disease

The US food supply is among the safest in the world. The overall high quality of life enjoyed by Americans can be attributed, in part, to an abundant, nutritious and relatively risk-free food supply. Nevertheless, every year an estimated 76 million people in the United States become sick, 300,000 are hospitalized and approximately 5,000 die as a result of the basic human activity of eating (US Centers for Disease Control, 2001a). The annual economic cost of foodborne diseases to the US economy is estimated to be several billion dollars (Satcher, 1996).

Ingestion of foods contaminated with bacteria, viruses and parasites is a major world public health issue, especially in developing countries. Particularly susceptible are infants, young children, the elderly, pregnant women and immunocompromised individuals. According to the World Health Organization (WHO), foodborne diarrhea is one of the most common illnesses of children and one of the major causes of infant and childhood mortality in developing countries. The WHO estimates that children age five and younger suffer 1.5 billion episodes of diarrhea annually from consumption of both unsanitary drinking water and tainted foods, resulting in over 3 million premature deaths. Repeated childhood bouts of diarrhea have dire long-term consequences including malnutrition, increased vulnerability to many diseases and stunted physical and mental development. The WHO estimates that approximately 2–3% of cases of foodborne disease outbreak lead to long-term ill health (WHO, 1999).

Economically, foodborne diseases exact a huge price in treatment, case investigation, work absence and lost human potential due to long-term damaging effects (WHO, 1999). Further, developing nations, which experience the highest rates of foodborne disease, can least afford to address the problem effectively. Although the safety of the US food supply is generally not a subject of concern, complacency is a dangerous attitude. Combating foodborne diseases requires the constant vigilance of many segments of society and their awareness of the changing nature of the challenge.

Safe practices are critical at every stage of food production and handling, all along the path leading to, *and including*, the consumer's kitchen. Opportunities for food contamination and cross-contamination abound in home kitchens. Consumer awareness of safe food preparation and storage practices helps guard against foodborne illness originating in the home.

Trends in Foodborne Disease Outbreak

The majority of foodborne illness cases arise from the consumption of foods of animal origin. Foods traditionally implicated in outbreaks include undercooked meat and poultry, seafood and unpasteurized milk. More recently, scientists have discovered pathogens in foods once believed incapable of supporting their growth. Such foods include eggs, juices, tomatoes, apple cider and lettuce (Prier and Solnick, 2000). While scientists and health experts work to understand, prevent and combat food contamination, their efforts have not kept pace with certain modern developments that exacerbate the health problem. Foodborne illness originating from eating contaminated fruits and vegetables, already prevalent in developing countries, is becoming increasingly common in developed countries (WHO, 1998). There are several possible reasons for this. The increasing globalization of food trade means that contaminated fruits and vegetables may be widely distributed. The susceptibility of foods to infection increases with lengthening transit times.

Further, as the elderly population increases, the average resistance to foodborne disease decreases, resulting in a greater portion of the population succumbing to illness from tainted foods. Not only is the elderly population increasing, but also, by virtue of rapidly paced medical advances, many more immunocompromised individuals are surviving. These include people with chronic rheumatological disease, cancer, solid-organ transplantation and AIDS (WHO, 1998). Such individuals' compromised immune systems make them more vulnerable to foodborne illness.

Changes in eating habits also may contribute to increasing numbers of cases of foodborne illness stemming from contaminated produce. Many are heeding the advice of health experts to increase their consumption of fresh fruits and vegetables. The modern consumer demands a wide variety of these products year-round, and with fewer preservatives (Zink, 1997). This demand fuels the importation of produce from countries with variable food safety standards. It is believed that the number of foreign food items sold in the US increased by 50%, from 2.7 million items in 1997 to 4.1 million in 2000 (Winter, 2001). Finally, according to Collins (1997), the typical American over the age of eight is eating four restaurant meals every week. Increased consumption of restaurant-prepared meals increases the potential for sickness resulting from improper food handling in restaurant kitchens.

Chlorination Protects Public Health

Historically, chlorine is one of mankind's most trusted weapons in the war against infectious waterborne diseases. Drinking water chlorination, first introduced in Great Britain in the early 1900's and shortly afterwards in the US, immediately improved the quality of life wherever it was employed. Chlorination and filtration of raw water are responsible for the virtual elimination of serious waterborne diseases such as cholera, typhoid, dysentery and hepatitis A (White, 1986). *LIFE* magazine, in rating the 100 most important historical events of the past millennium, called drinking water chlorination and filtration "…probably the most significant public health advance of the millennium" (Anonymous, 1997).

While chlorine's role in protecting against waterborne disease is widely recognized, chlorine also plays a vital role in the safe production of a wide variety of foods.

The Micro-Culprits of Foodborne Illness

Bacteria and viruses are the most common causes of foodborne illacness; protozoa may also cause sickness. Among bacteria, *Campylobacter, Salmonella, E. coli 0157:H7* and *Vibrio* cause the majority of foodborne sickness cases. The Norwalk viruses (also known as caliciviruses), are common culprits in foodborne illness, but are rarely diagnosed due to the unavailability of the diagnostic laboratory test.

Hepatitis A is a virus that infects the liver and causes the disease hepatitis A. *Toxoplasma gondii* and *Cryptosporidium parvum* are common parasitic protozoa that cause foodborne illness. Table 1 lists pertinent information on each of these common microorganisms.

Table 1: Common Foodborne Pathogens[1]

Pathogen	Infection Symptoms in Humans	Pathogen Reservoir	Cause of Infection
Bacteria			
Campylobacter	Fever, diarrhea, abdominal cramps, nausea, vomiting; Most commonly identified cause of diarrheal illness in the world; May cause Guillain-Barre syndrome.	Intestines of healthy birds; Raw poultry meat, cattle and sometimes swine.	Eating undercooked chicken or foods contaminated with juices from undercooked chicken; In developing countries: unchlorinated drinking water supplies, e.g., wells, contaminated with poultry feces.
Salmonella	Fever, diarrhea, abdominal cramps, headache.	Intestines of birds, reptiles and mammals.	Spread to humans by a variety of foods of animal origin, e.g., undercooked poultry, contaminated eggs (eaten raw) and raw milk; May invade the bloodstream in persons of poor health or weakened immune systems, causing life-threatening infections.

Table 1: Common Foodborne Pathogens[1] (Continued)			
Pathogen	**Infection Symptoms in Humans**	**Pathogen Reservoir**	**Cause of Infection**
E. coli O157:H7	Severe, bloody diarrhea, painful abdominal cramps; not much fever; May cause acute kidney failure, hemolytic uremic syndrome, in children.	Cattle and similar animals; also resides in humans.	Consuming food or water that has been contaminated with microscopic amounts of cow feces; Contaminated raw milk.
Vibrio parahaemolyticus	Watery diarrhea, abdominal pain.	Estuarine and marine environment and fish and seafood from those environments.	Consuming raw, improperly cooked, or cooked, recontaminated fish and shellfish.
Viruses			
Norwalk-like virus	Acute gastrointestinal illness, usually with more vomiting than diarrhea; Headache, myalgia and low-grade fever.	Infected persons for up to 2 days after diarrhea stops.	Contact with infected persons/food handlers.
Hepatitis A	Infects the liver and causes hepatitis A virus: fever, malaise, nausea, abdominal discomfort, dark urine and jaundice.	Feces of infected people; Poor sanitation and crowding facilitate transmission.	Person-to-person fecal-oral route by infected food handlers.
Protozoa			
Toxoplasma gondii	No symptoms but possible diarrhea; Infected pregnant women may pass the disease to their fetuses, resulting in death of the fetus or severe health effects, such as mental retardation.	Found in virtually all animal foods.	Consuming raw or undercooked meat or contact with cats that shed cysts in their feces during acute infection.
Cryptosporidium parvum	Profuse watery diarrhea; Life-threatening among the immunocompromised.	Waterborne or found in animal manures.	

1 Adapted from US CDC (2001b), US FDA on-line "Bad Bug Book" (as viewed 8-16-01), and personal communication with Dr. Fred Reiff (10-4-01).

Studies Indicate Contaminated Foods May Cause More Than Gastrointestinal Illness

Besides the expected gastrointestinal upset, other chronic diseases may result from foodborne infections. The US Centers for Disease Control and Prevention (CDC) (2001a) reports that in the past fifteen years, several important diseases of previously unknown cause have been determined to be complications of foodborne infections. Examples are Guillain-Barre syndrome, which can be caused by *Camplyobacter* infection, and hemolytic uremic syndrome (acute kidney failure in children), caused by *E. coli O157:H7*. In addition, *Salmonella* infection may produce reactive arthritis and serious infections, while *Listeria* can cause meningitis and stillbirths. In the future, further associations between diseases and food contamination may be uncovered.

Human Infection with Foodborne Pathogens

How are harmful microorganisms transmitted to people? Healthy animals raised for food host a variety of microbes, especially in their intestines. These microbes can transfer to meat and poultry during animal slaughter. Fruits and vegetables may be contaminated if they are irrigated or washed with waters contaminated with animal manure or human sewage. Filter feeding shellfish concentrate bacteria, such as *Vibrio*, that are naturally present in sea water, or other microbes originating in human sewage disposed of in marine waters. During food processing, infected human food handlers may contaminate foods by introducing microbes by hand contact. Alternatively, food may be contaminated by contact with contaminated surfaces, including work surfaces and utensils. Fabrics and sponges used to wipe surfaces also may transfer pathogens. Cross-contamination is the "…transfer of harmful substances or disease-causing microorganisms to food by hands, food-contact surfaces, sponges, cloth towels and utensils that touch raw food, are not cleaned, and then touch ready-to-eat foods. Cross-contamination can also occur when raw food touches or drips onto cooked or ready-to-eat foods" (Partnership for Food Safety Education On-Line Glossary).

Combating Foodborne Disease with Chlorine

Chlorine is a highly effective yet inexpensive weapon used in the battle to control foodborne disease. Chlorine generally is applied to contaminated surfaces in the form of elemental chlorine (chlorine gas) or a bleach solution made from either liquid sodium hypochlorite or granular calcium hypochlorite. These three forms of chlorine have been approved for use by the US Environmental Protection Agency and by individual states. General statements about chlorine in this document refer to these three commonly used chemical forms. The inhibitory or lethal activity depends on the amount of free available chlorine in the solution (in the form of hypochlorous acid, HOCl, present in bleach and chlorine solutions) that comes in contact with microbial cells. Free chlorine disinfects by chemically disrupting bacterial cell walls and membranes through oxidation of a chemical group known as the thiol group (WHO, 1998). Many viruses and protozoa are also inactivated by chlorine. Thus, chlorine is a powerful weapon used to inactivate harmful microorganisms and help prevent the spread of disease.

To minimize chlorine waste and optimize its efficient use, chlorine concentrations in sanitizing solutions should be monitored. The concentration of the fast-acting, antimicrobial hypochlorous acid, the chemical species providing free available chlorine to disinfectant solutions, is a function of pH. Between pH 6.5 and 7.0, HOCl exists as 95-80% of the free chlorine concentration. At pH greater than 8, the free chlorine concentration is less than 20%. To complicate matters, the paper test strips and colorimetric kits used to monitor chlorine do not distinguish between the presence of HOCl and a far less active chemical species, hypochlorite (OCl-). Therefore, to maintain a given free chlorine concentration, it is necessary to monitor and adjust the pH of disinfectant solutions (Suslow, 2000). Efficient use of chlorine for various food industry disinfection purposes can reduce costs (especially by minimizing machinery and equipment corrosion) and the negative environmental impact of wasting chlorine (Denny, 2000).

Chlorine in Food Production

On the Farm

In the production of safe, nutritious foods, chlorine's first role is on the farm. Chlorinated water, used for irrigation and livestock watering, lowers the risk of waterborne contamination to crops and farm animals. Chlorine also prevents the formation of bacterial slime and biofilms on irrigation equipment used to deliver water to crops (Suslow, 2000).

Recently, scientists at the Agricultural Research Service in College Station, Texas, reported that the chlorine-containing compound sodium chlorate, fed in low doses to cows and pigs prior to slaughter, selectively kills *Salmonella typhimurium* and *Escherichia coli 0157:H7*. The CDC estimates about 1.4 million cases of salmonellosis and 73,000 cases of diarrheal illness are caused by these two pathogens annually (USDA, 2001).

Routine seed disinfection is achieved by soaking seeds in chlorinated water, often with heating, to reduce the potential for viral, bacterial and fungal disease epidemics (Suslow, 2000). Recent outbreaks of *E. coli* and *Salmonella* in raw alfalfa and clover sprouts in the US and Japan prompted a review of industry practices by the US Food and Drug Administration and the California Department of Health Services. A series of safety measures were introduced in the US in 1999, including treating sprout seeds with chlorine dilutions and regular testing of irrigation water. Sprouts, considered ready-to-eat foods, are finished in warm, wet, dark conditions that are ideal for microbial growth (Green, 2001). Researchers have found that presoaking contaminated sprout seeds in a 20,000 mg/liter calcium hypochlorite solution reduces the risk of infection (Brooks et al., 2001).

Chlorine is an effective, inexpensive agent used to help manage post-harvest diseases affecting fruit and vegetable crops. Many fruits and vegetables are treated in flumes, water dump tanks, spray washers or hydrocoolers to which chlorine is added (Suslow, 2000). Up to 30% of harvested crops, especially highly perishable items such as tomatoes, squash and peaches, may be lost to post-harvest disease, according to the North Carolina Cooperative Extension Service. Investments made to save harvested crops are usually less costly and less environmentally damaging than efforts to increase production. Currently, chlorination is one of the few chemical options available to combat post-harvest disease. Various fungicides and bactericides that had been used alone or in combination with chlorine in the past have been removed from the market due to economic, environmental or health concerns.

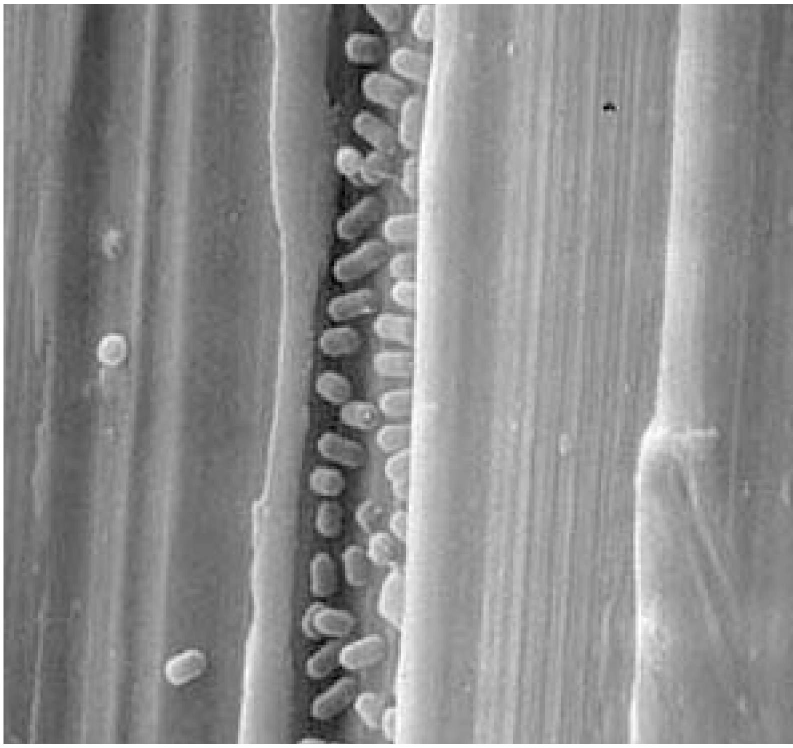
Up to 30% of harvested crops may be lost to post-harvest disease.

Effective chlorination of harvested crops depends upon frequent monitoring of the chlorine solution and an understanding of the various factors involved. According to the North Carolina Extension Service, these factors include the pH of the solution, chlorine concentration, water temperature, amount of organic matter present, exposure time and the growth stage of the pathogens present.

In Food Processing Facilities

The usefulness of chlorine is abundantly evident in food processing facilities where it is used extensively to prevent food contamination. Food processing facilities rely heavily on chlorine to disinfect various food and food-contact surfaces. Chlorine also is used frequently as a whitening agent to remove stains on equipment and walkways.

Chlorine quickly kills microorganisms on food surfaces, producing a lethal effect in the first few seconds of treatment. Unlike the chlorination of a liquid medium, such as raw water in which chlorine is effectively and uniformly dispersed, chlorine disinfection of solid surfaces generally presents a more difficult challenge. Physical and chemical characteristics of surfaces involved in food production vary greatly. Food surfaces themselves vary in geometric area, texture, pH and temperature. These surface properties influence the efficiency of chlorine disinfection. For example, the convoluted surface of a cantaloupe harbors microorganisms more efficiently than the smooth surface of a watermelon. (In June, 2001, in fact, there were two deaths and many cases of food poisoning across 14 US states attributed to *Salmonella*-infected cantaloupes grown in Mexico. *Salmonella* are believed to be transferred from the infected cantaloupe rind to the interior fruit via cutting knives.) Similarly, food-processing machinery with numerous interconnecting parts of various shapes, sizes and materials can be extremely difficult to decontaminate. Even a stainless steel table surface may present a disinfection challenge, given the ability of bacteria to colonize microscopic crevices (see photomicrograph below).



Photomicrograph of *L. monocytogenes* bacteria colonizing crevice in stainless steel food preparation surface.

The relative temperatures of food tissue and disinfectant help determine the effectiveness of disinfection. The temperature of wash water should be at least 10ºC higher than that of the fruits or vegetables to achieve a positive temperature differential, and to minimize the uptake of wash water through stem tissues or open areas in skin or leaves (Bartz and Showalter, 1981; Zhuang et al., 1995).

In addition to the consideration of surface properties and temperature, the particular varieties of microorganism(s) infecting the host surface help determine the effectiveness of disinfection. It is known, for example, that among bacteria, *Salmonella*, *Escherichia coli* and *Shigella* are less resistant than *Listeria monocytogenes*.

Researchers have developed a method to allow residual chlorine to remain in water after it is used to wash foods. The residual chlorine is an added measure of disinfection protection. The method has become known as "in-plant chlorination" (Griffin, 1946). Fruits, vegetables, poultry products, eggs, fish, frog legs and nut meats are washed with chlorinated water prior to being sold to the public or undergoing additional processing. In addition, flours are bleached with chlorine. The advantages of in-plant chlorination include odor and slime reduction, reduced clean-up time, lower bacterial counts on finished products and no apparent corrosion of metal equipment with continuous contact (Ritchell, 1947).

Meat and Poultry Industries

Chlorine solutions are used in many facets of meat and poultry processing, including worker hand, foot, shoe and boot sanitizing; equipment cleaning, sanitizing and whitening; and meat and poultry disinfection. Birds in poultry slaughtering facilities are cooled in chillers to which a chemical disinfectant, usually chlorine, is added. Chlorine in the chiller water reduces microbial content of the poultry and prevents cross-contamination. Beef carcasses, on the other hand, are washed with plain tap water as the organic material associated with beef quickly deactivates chlorine (Brashears, 2000).

Dairy Industry

The dairy industry was the first of the food industries to exploit the germicidal and deodorant properties of chlorine. Cheese plants are the largest users of chlorine in the dairy industry (Vavak, 2000). The Grade "A" Pasteurized Milk Ordinance (US FDA, 1995), issued by the US Department of Health and Human Services, specifies the officially approved methods of sanitation for dairy plants. Chlorine compounds used for dairy sanitation include calcium and sodium hypochlorite and certain organic chlorine compounds.

Egg Industry

Chlorine, combined with anionic detergents, effectively removes protein residues, and to a lesser extent, carbohydrate residues from egg shell surfaces. The chemical also reduces bacteria levels on egg shells. Due to the high pH and organic load of egg wash water, chlorine serves more as a cleaning compound than a sanitizer in these solutions (McKee, 2000).

Fish and Seafood Industry

Chlorine, in the form of sodium and calcium hypochlorite, is used in seafood processing sanitation applications. Scientists have found that the human pathogen *Aeromonas hydrophila*, commonly isolated from seafoods, forms biofilms on stainless steel within a three-minute contact time (Bal'a et al.,1999). Furthermore, they found the complexity of biofilms to increase with time at room temperature. Chlorine applied to infected stainless steel inactivates the biofilms. The effectiveness of chlorine on such biofilms is greatest when it is applied soon after infection.

Fresh Produce Industry

Chlorine is used extensively as a disinfectant in wash, spray and flume waters in the raw fruit and vegetable industry (WHO, 1998). The three forms of agricultural chlorine commonly used for fresh fruits and vegetables are chlorine gas, calcium hypochlorite and sodium hypochlorite.

Chlorine gas is generally restricted to use in very large operations and requires automated controlled injections systems with in-line pH monitoring. It is highly effective in situations in which soil, plant debris and decaying fruit or vegetables may enter early stages of washing and grading. Calcium hypochlorite, available as a granulated powder or compressed tablet, is the most common source of chlorine used for disinfection of produce and produce process water. Sodium hypochlorite, a water-based formulation, is the chlorine source frequently used in small-scale operations (Suslow, 2000).

An increasingly popular broad-spectrum antimicrobial agent used on foods, especially fresh produce, is chlorine dioxide. Chlorine dioxide is efficacious against bacteria on a variety of vegetables and fruits including carrots, mushrooms, asparagus, tomatoes, lettuce, cabbage, cherries, strawberries and apples. Reducing bacterial concentrations on produce increases the shelf lives of these foods. Chlorine dioxide also controls the fungal disease known as late blight and other secondary infections such as soft rot on stored potatoes (Khanna, 2002).

Chlorine in Food Transportation

As foods are transported ever greater distances for processing and distribution, the potential for food contamination rises. Chlorine is used to lower the risk of food contamination during transport.

Chlorine sanitization of storage containers prevents food contamination during transport. To optimize chlorine use efficiency, field bins, food totes, cartons and pallets should be sanitized *after* pre-washing to remove soils and organic debris as these materials quickly deplete free available chlorine (Suslow, 2000). Beyond its disinfection benefits, calcium hypochlorite is reported to improve the shelf life and disease resistance of produce by adding calcium to the cell walls of fruits and vegetables (Suslow, 2000).

Unsanitary ice used to chill produce during transportation can transmit diseases to produce that may cause decay of the produce or illness to the consumer. Ice made from potable, chlorinated water is an effective safeguard against external contamination during transport (Suslow, 2000).

Chlorine in
Food Preparation

Chlorine plays an essential role in the final destination of many fresh foods: restaurant and consumer kitchens. Infectious germs can spread quickly when food is not prepared and stored safely, causing foodborne illness. As consumers carry out the final stages of food preparation, dilute solutions of chlorine bleach (1-3 tablespoons household chlorine bleach in one gallon of water) are recommended for use in sanitizing cutting boards, countertops and cooking surfaces. (Separate cutting boards are recommended for meat and produce.) Cloths and sponges, which contact raw foods, should be soaked frequently in a stronger disinfecting solution of 3/4 cup bleach in one gallon of water. Washing raw foods with chlorine solutions is not generally advised[2].

In a comparison study of commercial and homemade disinfectants, scientists found that commercial products, such as chlorine-based household sanitizers, kill more than 99.9% of bacteria, including *E. coli* and *Salmonella*, while natural products such as vinegar and baking soda were not nearly as effective (Rutala et al., 2000). In addition, as opposed to antibacterial sanitizing products that attack only bacteria, chlorine products kill both bacteria and viruses, both of which can sicken people.

Experts estimate that washing hands often and thoroughly could eliminate *nearly half* the cases of foodborne illness. Futhermore, hot foods should be kept hot (at temperatures greater than 140ºF) and cold foods cold (at temperatures less than 40ºF). Microorganisms thrive in the range 40-140ºF, and toxins produced in that range may not be destroyed by reheating foods. Foods should be thawed in the refrigerator or microwave oven, or in a sealed package in cold water that is changed every half hour. Only pasteurized eggs should be used in recipes requiring uncooked eggs (Brody, 2001). Food should be stored in clean, covered

2 A recent study by US Department of Agriculture food microbiologist D. Ukuku suggests that washing cantaloupes with diluted chlorine or hydrogen peroxide solutions may protect against Salmonella contamination (Beaudin, 2001). (The fruit exterior should be thoroughly rinsed with water after washing and before cutting.) The Salmonella, living on the convoluted rind, contaminate cantaloupe interior fruit via cutting knives. Cantaloupe is a particularly difficult fruit to decontaminate due to its irregular exterior surface, with numerous crevices harboring soil and

containers. Consumers who heed food safety advice significantly increase their defenses against foodborne diseases.

Restaurant kitchens typically use sodium hypochlorite solutions to disinfect kitchen work surfaces and equipment. The Chlorine Chemistry Council, in concert with the Water Quality and Health Council and the National Restaurant Association, distributes food safety posters to restaurants listing detailed directions for sanitizing porous and nonporous food contact surfaces. The posters are available in English, Spanish, Cantonese and Mandarin (see below).

Germs that cause foodborne illness can't be seen, which is why sanitary cleaning practices are so important in restaurants.

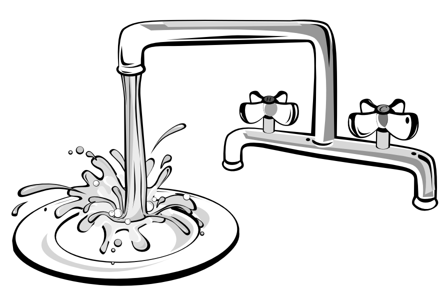
All Food Contact Surfaces Must Be Washed, Rinsed and Sanitized

1. WASH

WASH dishes, utensils, cookware, cutting boards, appliances and cooking surfaces with HOT, SOAPY WATER to remove visible soil.

2. RINSE

Thoroughly RINSE OFF soap and film.



3. SANITIZE

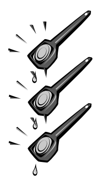
REGULAR CHLORINE BLEACH* diluted in water is an easy-to-use germ killer. Here are two effective bleach and water cleaning solutions:

FOR SURFACES THAT COME IN CONTACT WITH FOOD

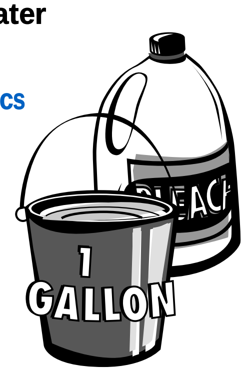
1 Tablespoon

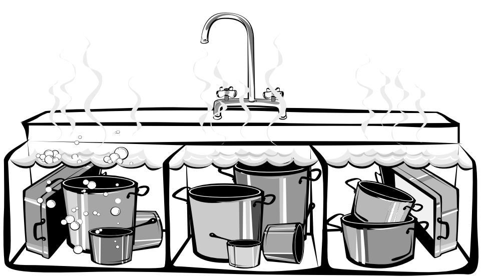
- **Nonporous Surfaces — Tile, Metal and Hard Plastics**
  Use 1 tablespoon liquid bleach per gallon of water (200 ppm‡). Leave wet for 2 minutes. Air dry.

3 Tablespoons

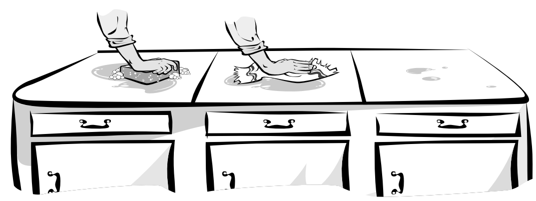


- **Porous Surfaces — Wood, Rubber or Soft Plastics**
  Use 3 tablespoons liquid bleach per gallon of water (600 ppm‡). Leave wet for 2 minutes. Rinse and air dry.





WASH, RINSE and SANITIZE pots, pans, glasses, dishes and utensils.



WASH, RINSE and SANITIZE other food contact surfaces.

CHLORINE CHEMISTRY COUNCIL
http://c3.org

WATER QUALITY & HEALTH COUNCIL℠

NATIONAL RESTAURANT ASSOCIATION®

* Recommendations are for regular chlorine bleach (5.25% sodium hypochlorite); do not use scented or color safe bleaches
‡ parts per million

Foodborne Disease Surveillance

Globalization of the food supply and changing life styles have complicated greatly the work of government public health officials in tracking the sources of foodborne disease outbreaks. In the past when food distribution networks were small and easily mapped, outbreaks could be relatively easily traced. Food distribution in the US today is much more complex. The classic case of a congregation's food poisoning from undercooked meat at a church supper would entail considerably less investigation than would infections of numerous widely dispersed individuals who may have consumed the same source of tainted food over a variable period of time. For example, a tainted airline meal could be served to some of the passengers on each of several different flights over a period of 24 hours. The consumers of the tainted meal become widely dispersed due to the fact the meal was served on several flights. Because of meal selection, not all those who ate in-flight meals become sick.

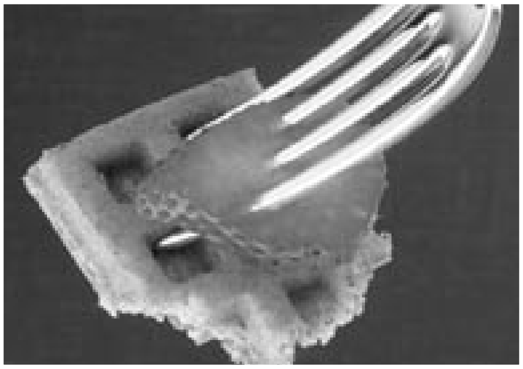
> **"The way to be safe is never to be secure."**
>
> **Thomas Fuller, 1608-1661**

According to the CDC (2001a), since many sick people do not seek medical attention, and since many who do are not tested, numerous cases of foodborne illness go undiagnosed. The CDC estimates that 38 cases of salmonellosis occur for every case that is diagnosed and reported to public health authorities. The CDC uses a DNA "fingerprinting" technology to more easily detect foodborne disease outbreaks across the United States. Using the new molecular subtyping network, *PulseNet* (http://www.cdc.gov/ncidod/dbmd/pulsenet/pulsenet.htm), state laboratories and the CDC can compare strains of *E. coli O157:H7* and an increasing number of other pathogens to detect widespread outbreaks.

The changing face of the enemy complicates the battle against foodborne illness. New foodborne pathogens will continue to be identified and rare but known pathogens may reemerge as public health threats. Improved surveillance allows a better understanding of the impact of these infections and how to prevent them. The CDC has enhanced foodborne disease outbreak investigation by applying sophisticated epidemiologic and microbiologic techniques to field investigations. Collaborative active surveillance systems include the CDC's electronic transmission system, the Public Health Laboratory Information System in state health departments and automated reporting and outbreak detection analysis (Satcher, 1996). Nevertheless, public health officials should continue to improve food safety surveillance and coordination among various levels of government. In response to recent concerns about potential terrorist threats, US officials are calling for a stronger public health infrastructure to respond effectively to public health emergencies of all types, including those related to contamination of the food supply. This effort may provide better links among local, state, regional and national public health offices, and improve notification and response regarding foodborne disease outbreaks. The United Nations Food and Agriculture Organization of the WHO recently called upon countries to upgrade their domestic food safety systems. The organization noted that developing countries, with no food safety systems in place, have an opportunity to "leap-forward," and capitalize on the experiences of industrialized countries, adopting modern food safety systems that work well (United Nations Food and Agriculture Organization, 2001).

Conclusions

Chlorine is a highly effective, inexpensive chemical disinfectant that is used to help maintain the safety of the nation's food supply. Chlorine has extensive critical uses all along the path from the farm to the fork. Tried and trusted methods of chlorine disinfection are well documented in numerous aspects of the food production industry. Untold numbers of cases of foodborne disease are prevented by chlorine disinfection of foods and food-contact surfaces. From the farm, to food handling, processing and transportation facilities, to restaurant and consumer kitchens, chlorine successfully inactivates a wide variety of disease-causing microorganisms associated with foods.



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