https://doi.org/10.4315/FPT-24-048

Cleaning: A Retail and Foodservice Perspective

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Surface sanitation is used to mitigate the transmission of infectious agents and is the collective process of washing a surface then rinsing it with potable water to remove debris and residual cleaning agent. If necessary and depending on surface type, contamination event, or regulatory requirement, an antimicrobial agent (chemical sanitizer or disinfectant) registered with the Environmental Protection Agency or heat (steam or hot water) can be applied to the surface to reduce or inactivate pathogenic microorganisms. The absence of universally defined terms and regulations pertaining to the various stages of surface sanitation has resulted in confusion, potentially leading to inadequate sanitation practices and persistent surface contamination. We addressed this issue by raising awareness of the significance of surface cleaning and elucidating the fundamental principles, key considerations, and potential areas for improvement concerning surface cleaning. Specific topics covered include a comprehensive description of surface cleaning, barriers hindering effective surface cleaning, correlation between contamination and foodborne disease outbreaks, and variations among cleaning agents. To maintain conciseness and relevance, the exclusive focus is on hard, nonporous surfaces, which have been identified as potential sources for the transmission of pathogenic microorganisms associated with foodborne illnesses.

INTRODUCTION

In the past decade, around 17% of retail foodservice establishments experienced permanent closures *(16)*. Simultaneously, the surviving establishments implemented operational adaptations, which included the integration of self-ordering kiosks, expansion of al fresco dining spaces, and increased use of kitchen automation. Infection prevention and control protocols within these establishments also changed. A notable development was the adoption of surface sanitation as a prominent and widely discussed strategy aimed at mitigating the transmission of infections caused by pathogenic microorganisms such as viruses and bacteria. This heightened focus on surface sanitation can be attributed, in large part, to the profound impact of the recent COVID-19 pandemic on the perceptions and concerns of both end users and operators within the foodservice industry.

Pathogenic microorganisms can be transmitted through direct contact with an infected individual or indirect contact with contaminated surfaces or airborne droplets. Cross-contamination can occur when previously uncontaminated surfaces become inadvertently infected with pathogenic microorganisms. Surface sanitation aids in preventing cross-contamination caused by indirect transmission through contact with a contaminated surface. Surface sanitation is the collective process of washing (i.e., removing soil and food debris from a surface with an appropriate cleaning agent) followed by rinsing with potable water to remove debris and residual cleaning agent. If necessary and depending on surface type, contamination event, or regulatory requirement, an antimicrobial agent registered with the Environmental Protection Agency (EPA) (i.e., chemical sanitizer or disinfectant) or heat (i.e., steam or hot water) is

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TABLE 1. Definitions related to surface sanitation *(32)*

Term	Definition	Source
Antimicrobial agent	Substance or mixture of substances used in sanitization and/or disinfection as specified	This article
Cleaning agent	Chemical or physical product that cleans	This article
Detergent	Substance or mixture of substances used for the wash step	This article
Disinfection	Application of "a substance, or mixture of substances, that destroys or irreversibly inactivates bacteria, fungi and viruses, but not necessarily bacterial spores, in the inanimate environment"	40 CFR 158.2203[a]
Sanitization	Application of "a substance, or mixture of substances, that reduces the bacteria population in the inanimate environment by significant numbers but does not destroy or eliminate all bacteria. Sanitizers meeting Public Health Ordinances are generally used on food contact surfaces and are termed sanitizing rinses"	40 CFR 158.2203
	"Application of cumulative heat or chemicals on cleaned food contact surfaces that, when evaluated for efficacy, is sufficient to yield a reduction of 5 logs, which is equal to a 99.999% reduction of representative disease pathogenic microorganisms of public health importance"	*(32)*
Surface cleaning	First (wash) and second (rinse) steps of the process of surface sanitation, not the entire process	This article
Surface sanitation	Collective process of washing (i.e., removing soil and food debris from a surface by using an appropriate cleaning agent) followed by a rinse with potable water to remove debris and residual cleaning agent, then application of antimicrobial agent	This article

[a]CFR, Code of Federal Regulations.

applied to the surface to reduce and/or inactivate pathogenic microorganisms.

Despite the importance of the surface sanitation process for preventing contamination, regulations lack standard definitions of the actions and terms for surface sanitation and often fail to describe all the steps in the process. For example, the terms "antimicrobials," "disinfection," and "sanitizing" are all defined in various regulations, whereas the terms "clean," "wash," and "rinse" are not defined *(Table 1)*. The lack of standardized definitions makes it difficult to determine whether surface sanitation is being performed correctly. Some guidelines use the term "surface cleaning" to mean "surface sanitation." Surface cleaning is the first (wash) and second (rinse) steps of the process of surface sanitation and not the entire process, which also includes the application of an antimicrobial agent. This distinction is important because these two steps (washing and rinsing) are often not given the same level of critical attention as the antimicrobial step.

The absence of universally defined terms and regulations pertaining to the various stages of surface sanitation has resulted in confusion among end users, potentially leading to inadequate sanitation practices and persistent surface contamination. The present article addresses this issue by raising awareness of the significance of surface cleaning *(Fig. 1)* and elucidating the fundamental principles, key considerations, and potential areas for improvement concerning surface cleaning. The specific topics covered include a comprehensive description of surface cleaning, barriers that hinder effective surface cleaning, the correlation between contamination and foodborne disease outbreaks, and the inherent variations among cleaning agents. To maintain conciseness and relevance, the exclusive focus is on hard, non-porous surfaces within foodservice establishments, which have been identified as potential sources for the transmission of pathogenic microorganisms associated with foodborne illnesses.

WHAT IS SURFACE CLEANING?

In the United States, the U.S. Food and Drug Administration (FDA) Food Code *(32)* has provisions that address cleaning and sanitization. The Food Code represents the FDA's best advice for a uniform system of provisions to address the safety and protection of food offered at establishments, but the Food Code becomes law only after being adopted by a jurisdiction. In foodservice establishments, surfaces are classified as either food contact (i.e., surface used to prepare, serve, transport, and/or store food) or non food contact (i.e., surfaces that typically have no direct contact

FIGURE 1. Cleaning performance difference between two commercially available cleaning agents. Two identical dishes (first row) contain greasy soil with grease-dissolving dye. Dishes were cleaned with commercially available cleaning agents A (second row, left) and B (second row, right) according to each cleaning agent label use directions. After applying additional grease-dissolving dye to the cleaned dishes, previously invisible and lingering residual grease is more apparent on the dish that had been cleaned with agent B (third row, right). Agent A was better for cleaning the greasy soil. (Procter & Gamble Professional, 2023.)

with food). Sanitation provisions in the Food Code differ for food-contact and non food-contact surfaces because of the dissimilar risk profiles of these two types of surfaces. According to the Food Code, all surfaces must be washed and rinsed, whereas only food-contact surfaces need to be sanitized after washing and rinsing. Sanitizing can be difficult for items that have both food-contact and non food-contact surfaces, such as refrigerators and preparation tables. End users may be unclear about how to determine which parts of the surfaces fall into each category. One major gap within these Food Code provisions for food-contact surfaces is the major emphasis on the antimicrobial step and less emphasis on the surface cleaning steps (i.e., washing and rinsing), particularly in relation to how to determine whether a surface is clean. In the recent retail food risk factor study, the FDA *(33)* found that establishments can improve in meeting the sanitation goals outlined in the Food Code provisions, particularly regarding proper cleaning and sanitizing of food-contact surfaces.

In the case of bodily fluid contamination, the Food Code recommends that all surfaces, regardless of type, be cleaned (i.e., washed and rinsed) then disinfected *(Table 2)*. Disinfection is defined as destroying or inactivating pathogenic microorganisms, whereas sanitization is defined as reducing the pathogenic microorganisms to safe levels as determined by regulatory agencies. Although this guidance may seem straightforward, the Food Code could benefit from the inclusion of a technical and quantitative definition or performance standard to provide an opportunity for better determining what is considered "clean." The Food Code provides a definition for "sanitization" but not for "clean," "wash," or "rinse" *(Table 1)*. Consequently, end users such as establishment cleaners and regulators (i.e., environmental health specialists) often rely on their senses (sight and touch) to determine whether a surface is clean—the intended outcome after washing and rinsing. Because sensory evaluations are subjective and not very reliable *(12)*, objective performance measures of clean surfaces are needed.

Washing and rinsing a surface before using an antimicrobial agent is required because the cleaning agent and/or organic matter on the surface may impact sanitization efficacy through interference with antimicrobial chemistry. Organic matter that remains on an improperly cleaned surface also can be a source of pathogenic microorganisms. Food debris can harbor pathogenic microorganisms found in food or in the saliva of the person who ate the food, and soil provides nutrients and retains moisture, prolonging the growth and/or survival of microorganisms. However, surface washing and rinsing before using an antimicrobial agent is not necessary when the agent is designed and labeled to be used as both a cleaning agent and an antimicrobial agent; these products are commonly referred to as one-step products. Many disinfectants are designed to be one-step products; thus, they do not require surfaces to be cleaned before they are used unless the surface is heavily soiled.

TABLE 2. 2022 FDA Model Food Code, chapter 4 (equipment, utensils, and linens) excerpts for cleaning surfaces[a]

Food Code, chapter 4	Section, language[b]
Subpart 4-201. Durability and strength	4-201.11. Equipment and utensils. Equipment and utensils shall be designed and constructed to be durable and to retain their characteristic qualities under normal use conditions.
Subpart 4-202. Cleanability	4-202.11. Food-contact surfaces. (A) Multiuse food-contact surfaces shall be (1) smooth;[Pf] (2) free of breaks, open seams, cracks, chips, inclusions, pits, and similar imperfections;[Pf] (3) free of sharp internal angles, corners, and crevices;[Pf] (4) finished to have smooth welds and joints;[Pf] and (5) except as specified in ¶ (B) of this section, accessible for cleaning and inspection by one of the following methods: (a) without being disassembled,[Pf] (b) by disassembling without the use of tools,[Pf] or (c) by easy disassembling with the use of handheld tools commonly available to maintenance and cleaning personnel such as screwdrivers, pliers, open-end wrenches, and Allen wrenches.[Pf] (B) Subparagraph (A)(5) of this section does not apply to cooking oil storage tanks, distribution lines for cooking oils, or beverage syrup lines or tubes. 4-202.16. Nonfood-contact surfaces. Nonfood-contact surfaces shall be free of unnecessary ledges, projections, and crevices, and designed and constructed to allow easy cleaning and to facilitate maintenance.
Subpart 4-303. Cleaning agents and sanitizers	4-303.11. Cleaning agents and sanitizers, availability. (A) Cleaning agents that are used to clean equipment and utensils as specified under Part 4-6, shall be provided and available for use during all hours of operation.[Pf] (B) Except for those that are generated on-site at the time of use, chemical sanitizers that are used to sanitize equipment and utensils as specified under Part 4-7, shall be provided and available for use during all hours of operation.[Pf]
Subpart 4-501. Equipment	4-501.17. Warewashing equipment, cleaning agents. When used for warewashing, the wash compartment of a sink, mechanical warewasher, or wash receptacle of alternative manual warewashing equipment as specified in ¶ 4-301.12(C), shall contain a wash solution of soap, detergent, acid cleaner, alkaline cleaner, degreaser, abrasive cleaner, or other cleaning agent according to the cleaning agent manufacturer's label instructions.[Pf] 4-501.115. Manual warewashing equipment, chemical sanitization using detergent-sanitizers. If a detergent-sanitizer is used to sanitize in a cleaning and sanitizing procedure where there is no distinct water rinse between the washing and sanitizing steps, the agent applied in the sanitizing step shall be the same detergent-sanitizer that is used in the washing step.
Subpart 4-601. Objective	4-601.11. Equipment, food-contact surfaces, nonfood-contact surfaces, and utensils. (A) Equipment, food-contact surfaces and utensils shall be clean to sight and touch.[Pf] (B) The food-contact surfaces of cooking equipment and pans shall be kept free of encrusted grease deposits and other soil accumulations. (C) Nonfood-contact surfaces of equipment shall be kept free of an accumulation of dust, dirt, food residue, and other debris.
Subpart 4-602. Frequency	4-602.11. Equipment, food-contact surfaces and utensils. (A) Equipment food contact surfaces and utensils shall be cleaned (1) except as specified in (B) of this section, before each use with a different type of raw animal food such as beef, fish, lamb, pork, or poultry;[P] (2) each time there is a change from working with raw foods to working with ready-to-eat foods;[P] (3) between uses with raw fruits and vegetables and with time/temperature control for safety food;[P] (4) before using or storing a food temperature measuring device;[P] and (5) at any time during the operation when contamination may have occurred.[P]

TABLE 2. 2022 FDA Model Food Code, chapter 4 (equipment, utensils, and linens) excerpts for cleaning surfaces[a] (cont.)

Food Code, chapter 4	Section, language[b]
Subpart 4-602. Frequency	(B) Subparagraph (A)(1) of this section does not apply if the food-contact surface or utensil is in contact with a succession of different types of raw meat and poultry each requiring a higher cooking temperature as specified under § 3-401.11 than the previous type. (C) Except as specified in ¶ (D) of this section, if used with time/temperature control for safety food, equipment food-contact surfaces and utensils shall be cleaned throughout the day at least every 4 hours.[P] (D) Surfaces of utensils and equipment contacting time/temperature control for safety food may be cleaned less frequently than every 4 hours if (1) in storage, containers of time/temperature control for safety food and their contents are maintained at temperatures specified under chapter 3 and the containers are cleaned when they are empty; (2) utensils and equipment are used to prepare food in a refrigerated room or area that is maintained at one of the temperatures in the following chart and (a) the utensils and equipment are cleaned at the frequency in the following chart that corresponds to the temperature and (b) the cleaning frequency based on the ambient temperature of the refrigerated room or area is documented in the food establishment; (3) containers in serving situations such as salad bars, delis, and cafeteria lines hold ready-to-eat time/temperature control for safety food that is maintained at the temperatures specified under chapter 3, are intermittently combined with additional supplies of the same food that is at the required temperature, and the containers are cleaned at least every 24 hours; (4) temperature measuring devices are maintained in contact with food, such as when left in a container of deli food or in a roast, held at temperatures specified under chapter 3; (5) equipment is used for storage of packaged or unpackaged food such as a reach-in refrigerator and the equipment is cleaned at a frequency necessary to preclude accumulation of soil residues; (6) the cleaning schedule is approved based on consideration of (a) characteristics of the equipment and its use, (b) the type of food involved, (c) the amount of food residue accumulation, and (d) the temperature at which the food is maintained during the operation and the potential for the rapid and progressive multiplication of pathogenic or toxigenic pathogenic microorganisms that are capable of causing foodborne disease; or (7) in-use utensils are intermittently stored in a container of water in which the water is maintained at 57°C (135°F) or more and the utensils and container are cleaned at least every 24 hours or at a frequency necessary to preclude accumulation of soil residues. (E) Except when dry cleaning methods are used as specified under § 4-603.11, surfaces of utensils and equipment contacting food that is not time/temperature control for safety food shall be cleaned (1) at any time when contamination may have occurred; (2) at least every 24 hours for iced tea dispensers and consumer self-service utensils such as tongs, scoops, or ladles; (3) before restocking consumer self-service equipment and utensils such as condiment dispensers and display containers; and (4) in equipment such as ice bins and beverage dispensing nozzles and enclosed components of equipment such as ice makers, cooking oil storage tanks and distribution lines, beverage and syrup dispensing lines or tubes, coffee bean grinders, and water vending equipment (a) at a frequency specified by the manufacturer, or (b) absent manufacturer specifications, at a frequency necessary to preclude accumulation of soil or mold. 4-602.12. Cooking and baking equipment. (A) The food-contact surfaces of cooking and baking equipment shall be cleaned at least every 24 hours. This section does not apply to hot oil cooking and filtering equipment if it is cleaned as specified in subparagraph 4-602.11(D)(6). 4-602.13. Nonfood-contact surfaces. Nonfood-contact surfaces of equipment shall be cleaned at a frequency necessary to preclude accumulation of soil residues.
Subpart 4-603. Methods	4-603.11. Dry cleaning. (A) If used, dry cleaning methods such as brushing, scraping, and vacuuming shall contact only surfaces that are soiled with dry food residues that are not time/temperature control for safety food. (B) Cleaning equipment used in dry cleaning food-contact surfaces may not be used for any other purpose. 4-603.12. Precleaning. (A) Food debris on equipment and utensils shall be scraped over a waste disposal unit or garbage receptacle or shall be removed in a warewashing machine with a prewash cycle. (B) If necessary for effective cleaning, utensils and equipment shall be preflushed, presoaked, or scrubbed with abrasives.

TABLE 2. 2022 FDA Model Food Code, chapter 4 (equipment, utensils, and linens) excerpts for cleaning surfaces[a] (cont.)

Food Code, chapter 4	Section, language[b]
Subpart 4-603. Methods	4-603.13. Loading of soiled items, warewashing machines. Soiled items to be cleaned in a warewashing machine shall be loaded into racks, trays, or baskets or onto conveyors in a position that (A) exposes the items to the unobstructed spray from all cycles; and (B) allows the items to drain. 4-603.14. Wet cleaning. (A) Equipment food-contact surfaces and utensils shall be effectively washed to remove or completely loosen soils by using the manual or mechanical means necessary such as the application of detergents containing wetting agents and emulsifiers; acid, alkaline, or abrasive cleaners; hot water; brushes; scouring pads; high-pressure sprays; or ultrasonic devices. (B) The washing procedures selected shall be based on the type and purpose of the equipment or utensil, and on the type of soil to be removed. 4-603.15. Washing, procedures for alternative manual warewashing equipment. If washing in sink compartments or a warewashing machine is impractical such as when the equipment is fixed or the utensils are too large, washing shall be done by using alternative manual warewashing equipment as specified in ¶ 4-301.12(C) in accordance with the following procedures. (A) Equipment shall be disassembled as necessary to allow access of the detergent solution to all parts. (B) Equipment components and utensils shall be scraped or rough cleaned to remove food particle accumulation. (C) Equipment and utensils shall be washed as specified under ¶ 4-603.14(A). 4-603.16. Rinsing procedures. Washed utensils and equipment shall be rinsed so that abrasives are removed and cleaning chemicals are removed or diluted through the use of water or a detergent-sanitizer solution by using one of the following procedures. (A) Use of a distinct, separate water rinse after washing and before sanitizing if using (1) a 3-compartment sink, (2) alternative manual warewashing equipment equivalent to a 3-compartment sink as specified in ¶ 4-301.12(C), or (3) a 3-step washing, rinsing, and sanitizing procedure in a warewashing system for CIP equipment. (B) Use of a detergent-sanitizer as specified under § 4-501.115 if using (1) alternative warewashing equipment as specified in ¶ 4-301.12(C) that is approved for use with a detergent-sanitizer or (2) a warewashing system for CIP equipment. (C) Use of a nondistinct water rinse that is integrated in the hot water sanitization immersion step of a 2-compartment sink operation. (D) If using a warewashing machine that does not recycle the sanitizing solution as specified under ¶ (E) of this section, or alternative manual warewashing equipment such as sprayers, use of a nondistinct water rinse that is (1) integrated in the application of the sanitizing solution, and (2) wasted immediately after each application. (E) If using a warewashing machine that recycles the sanitizing solution for use in the next wash cycle, use of a nondistinct water rinse that is integrated in the application of the sanitizing solution.

[a]Surface cleaning comprises the first (wash) and second (rinse) steps of the process of surface sanitation but not the entire process.
[b]Superscripts P (priority item) and Pf (priority foundation item) are used in the original Code text. For a priority item, "(1) … a provision in this Code whose application contributes directly to the elimination, prevention or reduction to an acceptable level, hazards associated with foodborne illness or injury and there is no other provision that more directly controls the hazard. (2) 'Priority item' includes items with a quantifiable measure to show control of hazards such as cooking, reheating, cooling, handwashing." For a priority foundation item, "(1) … a provision in this Code whose application supports, facilitates or enables one or more priority items. (2) 'Priority foundation item' includes an item that requires the purposeful incorporation of specific actions, equipment or procedures by industry management to attain control of risk factors that contribute to foodborne illness or injury such as personnel training, infrastructure or necessary equipment, HACCP plans, documentation or record keeping, and labeling."

Both chemical (e.g., quaternary ammonium chloride compounds and chlorine-based products such as sodium hypochlorite or sodium dichloroisocyanurate) and thermal antimicrobials (i.e., water rinse hot enough for a food-contact surface to reach at least 160°F [71°C]) require direct contact with pathogenic microorganisms to kill or inactivate them. Soil remaining on a surface because the surface was not properly washed and/or rinsed can create a physical barrier preventing or limiting the antimicrobials from contacting pathogenic microorganisms. Proteins, carbohydrates, and other inorganic soils can decompose the active ingredient in oxidizing antimicrobials (e.g., chlorine based products and hydrogen peroxide) through oxidation reactions, potentially reducing antimicrobial activity below the minimum concentration required for an adequate reduction of target pathogenic microorganisms. Quaternary ammonium chloride compounds can bind to soils or other materials, reducing their effectiveness against pathogenic microorganisms. Thermal antimicrobial processes (e.g., hot water sanitization commonly used in warewashing machines, which are specifically engineered to efficiently process racks of soiled items within a short timeframe of seconds to minutes) must reach a minimum temperature to kill pathogenic microorganisms. However, lingering soils can hamper surface heating via an insulating effect, which impacts the time required to heat the surface and reduces the total time the surface will be at the minimum temperature needed to kill pathogenic microorganisms.

Barriers to implementation of surface cleaning

Surface sanitation works only when properly implemented. The Centers for Disease Control and Prevention (CDC) Environmental Health Specialists Network (EHS-Net), a collaboration created to improve public health practice, has conducted research to understand how foodservice establishment policies and practices contribute to foodborne outbreaks. Both the FDA's retail food risk factor study and this research conducted by the CDC through EHS-Net have revealed that establishments with robust food safety management systems, including written policies, ongoing training, and active monitoring, are better equipped to prevent outbreaks and use proper surface sanitation practices *(4, 20, 25, 28, 33)*. In one EHS-Net study, food workers were interviewed to better understand perceived barriers to proper surface sanitation. Food workers reported time constraints, high business volume, pressure from management and co-workers, and availability or accessibility to necessary tools as reasons for improper sanitation *(14)*. Other researchers have identified similar barriers to surface sanitation implementation *(24, 35)*. Most of these studies have been focused on sanitizing food-contact surfaces. Further research is required to better comprehend the barriers associated with training, education, and behaviors that hinder the effective implementation of proper surface cleaning to prevent contamination *(24, 35)*.

Foodborne outbreaks associated with cross-contamination

A CDC analysis of 2006 to 2007 U.S. foodborne outbreak data indicated that 32 of 229 restaurant outbreaks were directly associated with insufficient sanitation practices for food equipment and utensils *(13)*. In a study published in 2007 in which data from the Committee on Control of Foodborne Illnesses of the International Association for Food Protection were examined, 21 of 816 reviewed outbreaks were directly attributed to inadequate sanitation measures *(29)*. Two additional studies of foodborne outbreaks from 1998 to 2012 revealed cross-contamination as a contributing factor in 710 (24%) of the analyzed outbreaks *(1, 3)*. Although the scope of the present article is limited to foodservice establishments, inadequate sanitation practices in food manufacturing facilities also have been linked to foodborne outbreaks *(5, 6, 11, 17, 19)*.

FUNDAMENTALS OF CLEANING

Regulatory framework

No regulatory framework exists to validate claims of cleaning agent performance, whereas a framework does exist for antimicrobials. In addition to the FDA, two other U.S. agencies, the EPA and CDC, provide guidance on surface cleaning, with each having a different role and scope.

EPA

Title 40 of the Code of Federal Regulations (CFR) comprises the primary environmental regulations in the United States. The EPA proposes these regulations, considers public feedback, and finalizes them as rules. Under the authority granted by the Federal Insecticide, Fungicide, and Rodenticide Act, the EPA regulates disinfectants and other antimicrobial products, overseeing their registration, distribution, sale, and use. The EPA sets standards and guidelines to ensure the safety, effectiveness, and proper utilization of these products. However, the term "clean" is not explicitly defined in 40 CFR. Nonetheless, it is implicitly expected that a "clean" surface will be free from visible soil that could interfere with the antimicrobial chemistry. Definitions for disinfection, disinfectants, sanitizing, and sanitizers can be found in 40 CFR 158.2203 and are further elaborated in the EPA Office of Chemical Safety and Pollution Prevention 810 Product Performance Test Guidelines.

FDA

The FDA assists state, local, tribal, and territorial agencies responsible for preventing foodborne disease through the development of model Food Codes and model Code interpretations. As the lead federal food control agency, The FDA promotes uniform implementation of national food regulatory policy among the several thousand federal, state, and local agencies and tribes that have the primary responsibility for the regulation and oversight of retail food operations. The Food Code is a model for best practices about how to manage food safety risks, including risk factors associated with surface cleaning in foodservice establishments. Although the Food Code does not include a definition of "clean," it does include regulatory provisions related to cleaning *(Table 2)*.

CDC

The CDC provides evidence-based infection control strategies, including surface cleaning guidelines for various settings and situations (e.g., clean-up procedures for vomitus *(9)* and after disasters *(8)*). These strategies are typically dependent on the pathogen (e.g., human norovirus or *Listeria monocytogenes*) because additional considerations need to be addressed for safety, selection of chemicals, and surface type and material. The CDC also provides subject expertise to advise the development of surface sanitation resources *(31, 34)*, industry guidelines *(7)*, and regulatory guidance. For example, the COVID-19 pandemic increased the need for guidance about surface cleaning because reports of poisonings and injuries from unsafe use of cleaning agents and antimicrobials increased *(10)*. In response, the CDC developed guidance on how to clean, sanitize, and/or disinfect with chlorine-based solutions. Current CDC guidelines do not address products formulated with active ingredients other than chlorine for use in foodservice establishments.

Science of cleaning agents

Cleaning agents. Cleaning agents (sometimes called detergents or cleaners) aid in removing organic and inorganic matter from surfaces during the wash step. Cleaning agents can be simple commoditized blends of ingredients or complex formulas designed to meet specific performance goals for a particular job. Cleaning agents and antimicrobials (i.e., sanitizers or disinfectants) are not interchangeable; cleaning agents do not kill pathogenic microorganisms, but antimicrobials do. Because of the wide variety of cleaning agents available and the many different types of soil to be removed, a single cleaning agent cannot and should not be used for all contamination events. Cleaning agents are formulated to work best under specific conditions (e.g., some work best on fats, some in warm water, others in hot water). Cleaning agents also should be compatible with the surface and with any other chemicals to be used in the operation (e.g., sanitizer or drying agent). Many types of cleaning agents are available. The most common cleaning agents found in foodservice establishments are kitchen degreasers; window, bathroom, floor, and multisurface cleaning agents; and all-purpose cleaning agents .

Cleaning agent formulations. Although composition and respective ingredient concentrations are unique to the cleaning application, the general formulation is essentially the same: surfactants, alkalinity enhancers (for nonacid cleaning agents), solvents, builders, dyes, and fragrances *(Table 3)* *(18, 26, 27)*. Surfactants, possibly the most important ingredient, are generally identified first on labels, dictating the remaining formulation. Commercially available surfactants are commonly classified into four broad types, anionic, cationic, nonionic, and amphoteric, based on how the ingredients work once solubilized in water. *Table 4* summarizes the chemical and performance properties of surfactant categories *(18, 26, 27)*.

Cleaning agents used to remove animal fats on surfaces rely on saponifying fat with highly alkaline ingredients (e.g., sodium hydroxide, also known as lye) or neutralized salts of carbonic acid, phosphoric acid, or silicic acid. Saponification involves a reaction of the fatty acid from the animal fat with the neutralizing alkaline ingredient, creating a soluble "soap" that can be flushed away, rendering the surface clean. Saponification is more effective when animal fats are first heated and softened, typically by soaking soiled surfaces in hot water before washing. The advantage of alkaline ingredients is that they are considered effective against animal-based fats and can be produced relatively inexpensively. However, these ingredients have disadvantages. First, high amounts of animal fats can rapidly or completely neutralize alkaline ingredients available for saponification (i.e., free alkalinity), thus requiring more cleaning agent to continue or complete the wash step. Second, traditional cleaning agents with high levels of alkaline ingredients are generally hazardous to handle and require proper safety training and personal protective equipment (e.g., eye and skin protection) not commonly used in establishments. Third, the performance of alkaline ingredients varies widely when tackling a large range of food soils. For example, unlike animal-based fats, polymerized vegetable oils are much more resistant to saponification by these types of formulas.

In addition to alkaline ingredients, cleaning agents also contain solvents (e.g., polyethylene glycol ethers) that help solubilize crystalized complex fatty acids and triglycerides and penetrate other fatty soils on the surface. Solvents act as a vehicle for other ingredients to penetrate deeper into the soil. Some also contain enzymes, naturally derived proteins that can break down complex food soils (e.g., egg yolk) and starch into smaller parts, facilitating the action of alkaline ingredients, solvents, and surfactants. Some contain builders, ingredients that condition the water used for washing as to not interfere with the functionality of the remaining ingredients and maximize performance. Other ingredients (e.g., fragrances and dyes) are incorporated to serve noncleaning functions, such as user and process safety (e.g., rapid identification of cleaning agent based on product color) or a pleasant sensory experience for the user.

Cleaning agent delivery formats. Dilutable concentrate and ready-to-use (RTU) formulas are the two primary delivery formats, with both having advantages and disadvantages. Their main difference is that dilutable concentrates require mixing with water before use, whereas RTU cleaning agents are used directly from the container.

TABLE 3. Summary of role of ingredients used to formulate cleaning agents *(18, 26, 27)*

Ingredient	Role in formulation	Ingredient examples
Surfactants	• Detach soils from a surface and keep them in suspension until they are washed away or wiped down • Improve wetting, i.e., how water "sheets" on a surface instead of beading • Modify product foamability and viscosity • Impart wash solution stability at elevated temperatures • Suspend soils and oils from wash solution to avoid soil redeposition	See *Table 4*
Alkalinity enhancers	Saponify fatty acids, especially of animal and vegetal origin, resulting in enhanced soil removal	• Hydroxide and carbonate salts of sodium and potassium • Silicate salts of sodium and potassium, which contribute alkalinity and provide corrosion protection to ceramic, metals such as aluminum, and glass
Solvents	• Facilitate the solubilization or remaining soils not saponified by alkalinity enhancers • Should be odorless, nontoxic, and nonflammable in the finished product and possess good oil solubility	• Glycol ethers, isopropyl alcohol, and ethanol • *d*-limonene and pine oil in certain applications
Builders	• Inhibit undesired effects of water hardness on cleaning, stability, and foaming, and on biocidal properties of formulations • Prevent spotting, tear drops, or undesired films • Prevent limescale deposition on surfaces, both warewashing and dishwashing machines	• Conjugated salts of polycarboxylic acid moieties • Functionalized anionic polymers
Fragrances and dyes	• Improve sensorial user experience through pleasant odors • Help identify products visually	Various

Dilutable concentrates are typically less expensive because they can be diluted with water to make a larger volume of cleaning solution (i.e., cleaning agent plus water for dilution), advantageous for large cleaning projects. Dilutable concentrates are also more versatile because they can be customized to meet specific needs (e.g., degree of soiling or surface type). Dilutable products are often viewed as more sustainable because they use less packaging, reducing packaging waste. One main disadvantage of dilutable products is that they take more time to prepare for application than do RTU products. If the user does not properly dilute the cleaning solution, it might not be effective or might even cause surface damage. Another disadvantage of dilutable products is that the hardness of the water used to prepare the cleaning solutions could negatively impact performance, and water hardness varies widely across the United States. Additional equipment also is needed (e.g., measuring cups or automated dispensers) with dilutable products to produce cleaning solutions. The main advantages of RTU products are that they do not require a dilution step, additional equipment is not necessary, and the product will exhibit consistent cleaning performance with every application. However, these products generally are more expensive.

Cleaning performance standards

No established regulatory framework currently exists to verify the efficacy of cleaning agents. Similarly, universally

TABLE 4. Summary of properties for surfactants commonly used in foodservice establishment cleaning agents *(18, 26, 27)*

Property	Anionic	Cationic	Amphoteric (zwitterionic)	Nonionic
Charge	Negative charge when dissociated in water	Positive charge when dissociated in water	Contain both anionic and cationic functional groups within the same molecule yet possess a net charge of zero	Do not ionize in solution nor is ionic character needed for aqueous solubility; solubility based on hydrogen bonding with surrounding molecules of water
Key chemical structure	Carboxylates, sulfates, sulfonates, and phosphates	Quaternary ammonium	Carboxylate or sulfate (anionic end) and quaternary nitrogen (cationic end) and aminoxides	Glycol, alcohol, ether, ester, ethylene oxide, and propylene oxide
Typical examples	Linear alkylbenzene sulfonate, methyl ester sulfonates, alcohol ether sulfate, alcohol sulfate, α-olefin sulfonates, and soaps (long-chain fatty acids)	Alkyl quaternary ammonium salts	Lauryldimethylamine oxide, cocamidopropyl betaines, lauryl betaine, and sultaines	Alkyl polyglycosides, alcohol ethoxylates, alkylphenol ethoxylates, and ethylene oxide/propylene oxide block copolymers
Pros	• Good wetting agents • Good foam generators • Best for removing particulate soil	• Freely soluble throughout the pH range • Excellent broad spectrum biocidal activity	• Excellent foaming and detergency • Compatible with other surfactants • Ability to improve the viscosity and stability of cleaning agent • Reduction of the irritating effects of harsher surfactants • Compatible with hard surfaces • Compatible with strong oxidants such as hydrogen peroxide and sodium hypochlorite • Low toxicity and biodegradable	• Superb detergency and wetting against greasy or oily soils • Low foaming • Good soil and pigment dispersion • Minimal visible residue • Compatible with cationic and anionic surfactants
Cons	• Sensitive to hard water and low pH • Mixed compatibility with oxidizers such as chlorine-based products and hydrogen peroxide • Incompatible with cationic surfactants and some organic solvents	• Biocidal activity negatively impacted in the presence of hard water and organic soil • Incompatible with anionic surfactants	• Betaines more expensive than other surfactants, and sultaines more expensive than betaines • At acidic pH, amine oxides behave as cationic surfactants and will precipitate out of solution in the presence of anionic surfactants	Mixed compatibility with oxidizers such as chlorine-based products and hydrogen peroxide

accepted standards for evaluating the performance of cleaning agents also are lacking. Consequently, end users must rely on the marketing claims on product labels. The American Society for Testing and Materials has developed a testing standard for the removal of bathroom soils from ceramic tiles, but no specific standard exists for food soil removal *(2)*. Standardization of performance standards is challenging because of the diverse range of soils that can potentially contaminate surfaces.

Monitoring and verification of surface cleaning

As per the Food Code, environmental surfaces must be cleaned before they come into contact with food in various situations, including handling different types of raw animal food, transitioning from raw foods to ready-to-eat foods, switching between raw produce and foods that require time and temperature control, using or storing a food temperature measuring device, and when there is a suspicion or likelihood of contamination. Surfaces that do not come into contact with food should be washed whenever there is visible accumulation of debris or dirt to prevent conditions that may attract pests.

Establishment management should ensure they provide feedback to staff on whether washing and rinsing of surfaces are being done correctly. The quality and depth of information provided depends on the monitoring method used *(Table 5)*. Sensory observations, based on sight, smell, and touch, are highly subjective but commonly used to evaluate whether a surface is clean because they mirror the potential customer's experience. Although senses provide valuable qualitative information to detect differences in the environment (e.g., identifying an odor source so it can be treated or seeing soil on a table, sensory observations vary widely from person to person and thus are neither consistent nor accurate. Objective methods are needed to replace or at a minimum supplement sensory observations.

One such objective method is bioluminescence quantification via surface swabbing. This process is used to evaluate whether a surface is clean based on the level of ATP *(23, 30)*. ATP is produced by bacteria, and nonmicrobial ATP can be found in food debris; generally, when swabbing for the presence of ATP produces negative results, the surface can be considered clean. Results can be obtained in minutes using a handheld luminometer unit. Because nonmicrobial ATP is found in food debris, a positive result should not be considered a direct indication of the presence of pathogenic microorganisms on a surface. Viruses (e.g., human norovirus and coronaviruses) do not produce ATP and cannot be detected with this method. Some chemicals (e.g., chlorine-based products and citric acid, often found in foods and drinks) can interfere with ATP measurements *(23, 30)*. Speedy results and relatively low cost make ATP swabbing an easy assessment tool as long as test limitations are clearly understood *(Table 5)*. This tool can be used to verify cleaning operations, but operators must understand how to use the data to inform corrective actions.

Special fluorescent markers applied to surfaces will glow when exposed to certain types of light. To be of use for indicating sanitation, these markers must be appropriate for use on food-contact surfaces; otherwise, they can be used on only non food-contact surfaces due to toxicity concerns. After a surface is cleaned, a UV light is used to determine whether the marks have been removed, indicating that the surface is clean. The disadvantage of fluorescent markers is that they cannot be used to determine whether a cleaning solution was properly prepared and used, only whether a "mark" was physically removed.

Dyne pens or test fluids can be used to measure the hydrophobicity (i.e., how well a surface can repel water) of a cleaned surface. Lower dyne readings indicate a more hydrophobic surface, where water will bead up, whereas higher readings indicate a hydrophilic surface that allows water to wet it. Soils such as grease and oil repel water and could be detected by this method. One disadvantage is that contaminants picked up during marking could reduce pen accuracy over time, leading to more frequent replacement and thus increased costs. Various surface materials and coatings have different "clean" readings. For example, glass has a much higher dyne reading than does stainless steel. With this method, an understanding of the "clean" reading of each surface material is needed to determine whether a surface is clean, making this method impractical for use in most establishments.

Microbial assessment methods are the "gold standard" for monitoring surface cleaning because they can directly and quantitatively measure microbial presence on a surface. Microbial methods typically involve swabbing a surface then transporting swabs to a microbiology laboratory where they are cultured and analyzed for specific metrics (e.g., identification and total population of specific pathogenic microorganisms). Although this method is the most direct evaluation of the presence of pathogenic microorganisms, it can be expensive. Results can take up to a week after sample collection, making it difficult to respond to issues in real time or to provide immediate feedback to staff. Thus, although objective methods are needed to verify clean surfaces, the technologies are not feasible and present challenges for many establishment operators.

FACTORS THAT AFFECT SURFACE CLEANING

Soil type and origin

Animal-based greasy soils (e.g., beef, chicken, and lard) are among the most difficult soils to remove. Greasy soils are complex, with large fatty acids and triglycerides that crystalize at room temperature. Both heat and a highly alkaline cleaning agent are required to remove them. Similar to animal-based fats, vegetable-based oils (e.g., canola, palm, soybean, and sunflower), composed of unsaturated and polyunsaturated

TABLE 5. Summary of currently available methods for monitoring of wash step efficacy *(23, 30)*

Monitoring method	Sensory observations	ATP swabbing	Fluorescent markers	Dyne pens/test fluids	Microbial assessment
Evaluation criteria	Subjective sensory perception (sight, smell, touch)	Quantification of ATP levels	Presence or removal of fluorescent marks under UV light	Measurement of hydrophobicity to determine water repellency	Direct assessment of microbial presence and identification
Consistency and accuracy	Varies widely from person to person; subjective and inconsistent	Speedy results, but positive ATP result is not a direct indication of pathogenic microorganisms; limited detection of certain viruses and interference from certain chemicals	Indicates physical removal of marks but does not assess cleaning solution preparation or proper use	Can be affected by contaminants over time; different readings for different surface materials	Direct and quantitative measurement of microbial presence; "gold standard"
Practicality	Easy and commonly used but limited reliability	Easy and relatively low cost; provides quick results but limitations must be understood	Limited to determining physical removal of marks; does not assess cleaning solution preparation	Impractical for most establishments due to different "clean" readings for surface materials	Expensive and time-consuming; results take up to a week.
Application	Provides qualitative information; not suitable as sole method	Can be used to verify cleaning performance when limitations are understood	Limited to determining physical removal of marks; does not assess cleaning solution preparation	Limited use due to different readings for surface materials	Most direct evaluation of pathogenic microorganism presence, but expensive and time-consuming

fatty acids, also can be difficult to remove. When exposed to heat, oxygen, and moisture (i.e., during cooking), unsaturated and polyunsaturated fatty acids can react with one another through polymerization, creating a hardened, viscous, and sticky coating. Removing this coating (similar to that found on a seasoned cast iron pan) requires high heat, mechanical action (e.g., scrubbing), and a cleaning agent. Consequently, cooked-on or baked-on vegetable-based oils and fats are much more difficult to remove than their original liquid forms. Aging (i.e., delaying washing of a soiled surface) and exposure to UV light can exacerbate the polymerization of unsaturated and polyunsaturated fatty acids. The presence of carbohydrates and/or proteins in oil residues also makes these residues more difficult to remove *(18, 26, 27)*.

The complexity of food debris is not exclusively correlated with the type of edible fats or oils. Grills, griddles, and bakeware often have charred organic and inorganic residues from proteins or seasonings. Hence, abrasive techniques (e.g., use of metal sponges or scrubbers) are often used in conjunction with a cleaning agent. From a cleaning agent formulation perspective, specialty ingredients that can penetrate and lift carbonaceous compounds could play an important role in improved product efficacy. However, these types of products are very complex to formulate *(18, 26, 27)*.

Colorful fruits, vegetables, and spices often leave visible color residues on surfaces. Tomato-based foods and some red spices such as paprika contain carotenoids, which are responsible for colors and stains on both porous and nonporous surfaces. These carotenoids behave like animal fats from a cleaning perspective, tending to be harder to remove from plastic surfaces (e.g., reusable storage containers or cutting boards). End users often rely on bleaching products to remove the visible stains. However, bleaching does not guarantee that the underlying soil has been adequately removed. Sodium hypochlorite is affected by organic matter and is an ineffective cleaning agent, despite its powerful antimicrobial benefits and bleaching properties. Thus, soaking items with carotenoid-based stains in a chlorine-based sanitizing solution can eliminate the color stain but will not necessarily remove soils, which may harbor microbes *(18, 26, 27)*.

Surface materials

The type of surface material affects cleaning agent performance. Fatty and oily soils have a higher affinity to plastic than to metal and so are more difficult to remove from plastic. Some plastics might be adversely affected by sustained high heat, so more powerful cleaning agents, longer cleaning time, or stronger mechanical action might be required to effectively clean these materials. For items composed of both metals and plastics (e.g., cutlery or some cooking pans), the metal parts may look clean but the plastic parts may not. These plastic sections are often high-touch surfaces (e.g., knife and pot handles) and thus can serve as vectors for cross-contamination *(18, 26, 27)*.

Surface function

In foodservice establishments, small items such as dishes, glasses, utensils, some pots and pans, and food equipment (e.g., mixer inserts and cutting boards) are typically cleaned in a warewashing machine or in the first compartment of a three-compartment sink. Some items are presoaked to loosen dried-on food residues before cleaning. Presoak products are formulated with more powerful solvents than other cleaners because no mechanical action is used during this step. All of these surfaces will differ in such factors as soil accumulation, chemical and physical changes from food soils during the aging or cooking process, and strength of attachment of food soils to the surface; thus, variations in the cleaning parameters are required to render different surfaces clean.

Cleaning parameters

In general, four parameters affect cleaning outcomes: product, mechanical action, time, and temperature *(18)*. The cleaning agent formulation dictates its performance against certain tough soils (e.g., polymerized unsaturated and polyunsaturated fatty acids, carotenoids, or greasy soils) on surfaces. Formulations that contain alkaline ingredients, solvents, surfactants, builders, and enzymes often work better for removing a wider variety of food debris and soil than do formulations that contain limited ingredients such as food-contact sanitizers or that rely primarily on alkalinity to saponify animal-based fats *(Fig. 2)*. The amount of each ingredient in the final formulation also affects soil removal. More force or harder scrubbing during the washing process improves sanitation results, resulting in cleaner surfaces. The use of abrasive tools such as metal or heavy-duty brushes, agitation, pressurized cleaning solutions, or high turbulence with recirculating sinks in advanced processes are more effective for removing food debris and soil than is presoaking. When strong mechanical action is not feasible or milder cleaning agents are utilized, it takes a longer for the cleaning solutions to interact with soils. Establishments may have pots and pans with baked-on food that must be presoaked for hours to remove the food. Higher water temperatures can also increase cleaning efficacy by softening solidified and aged food soils. More engineered formulations and higher concentrations of cleaning solution, stronger mechanical washing action, longer wash times, and higher wash water temperatures produce better cleaning results *(18, 26, 27)*. Establishment managers must include procedures in a well-developed food safety management system that detail the correct settings for product, mechanical action, time, and temperature for a given cleaning application.

Warewashing machines

Local health departments typically require warewashing machines that conform to the National Sanitary Foundation (NSF) Standard NSF/ANSI 3 *(22)*. This standard pertains to commercial washing machines that utilize detergent solutions to clean dishes, glasses, pots, pans, and utensils. In these machines, sprays of hot water or chemical sanitizing solutions are used to sanitize the items. The NSF/ANSI 3 standard includes guidelines for design, construction, assembly, installation, operation, and cleaning performance. Adherence to these guidelines ensures that the warewashing machine has the optimal capability to meet the sanitation requirements outlined in the Food Code for this specific type of equipment.

In these machines, powerful cleaning formulas are combined with mechanical action, such as pressurized wash solutions, at the highest allowable temperature. Two basic types of warewashing machines are conveyor units, typically used in high-throughput operations, and stationary single or double-rack machines, typically used when throughput is lower. Some machines continuously reuse the cleaning solutions, replenishing water and cleaning agents as needed to compensate for losses due to carryover or evaporation. Other machines flush out all cleaning solutions after processing each rack (i.e., dump and fill).

When cleaning solutions are reused, the cleaning agent should be capable of effectively functioning even in the presence of accumulated soils. When the cleaning solution is discarded after each load, the cleaning agent should be formulated in a way that minimizes the cost of replenishing the machine with fresh agent. Each option utilizes different

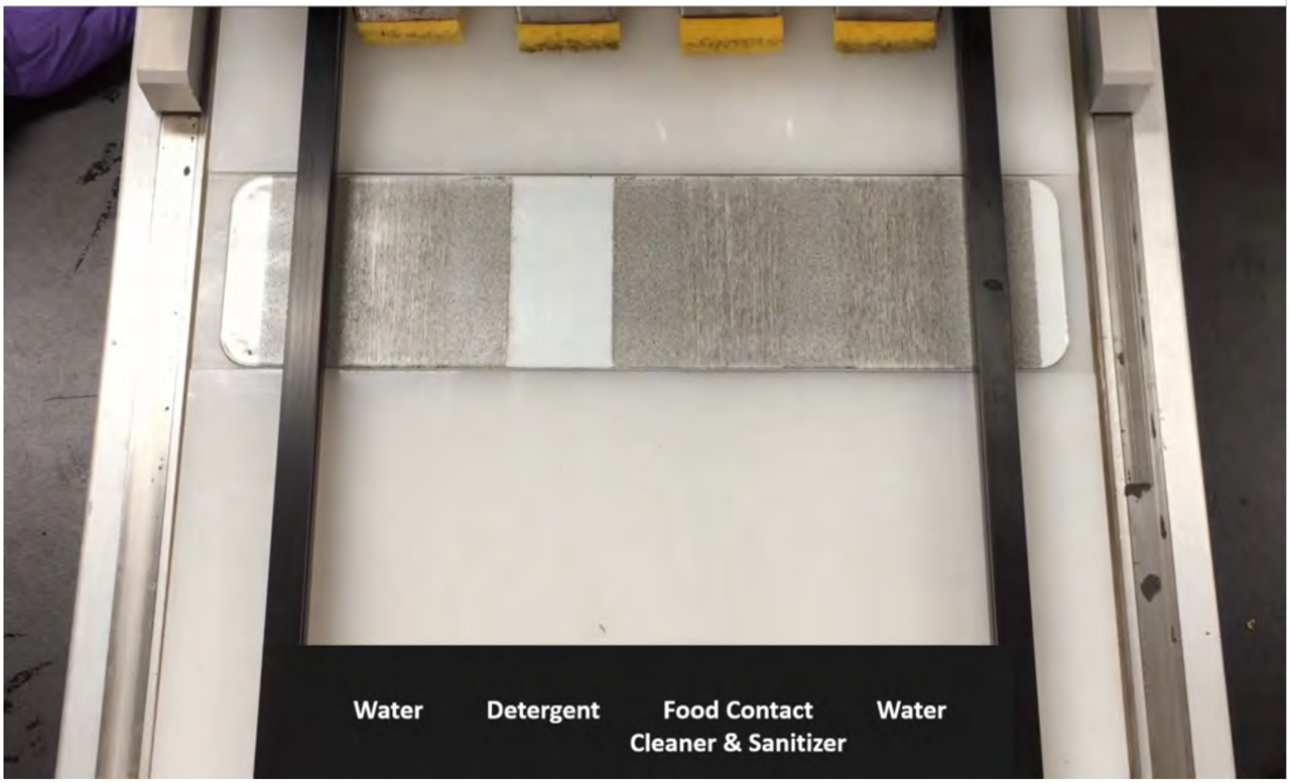

FIGURE 2. Kitchen-style baked-on greasy soil on a surface cleaned with a scrub tester. Cleaning agents were water (control, far left and right columns), a commercially available heavy duty dish-cleaning agent (detergent, second from left), and a food-contact cleaning agent and sanitizer product diluted as per label use directions (third slot from left). Sponges containing a fixed amount of each cleaning agent under identical pressure (via fixed weights) stroke the soil-coated slab 10 times. Qualitative soil removal after 10 strokes is depicted. (Procter & Gamble Professional, 2023.)

contact times, temperatures, and mechanical action to account for variations in cleaning agent usage.

In situations with lower warewashing throughput, cleaning agents commonly used in a manual three-compartment sink may be suitable. However, washing in a three-compartment sink typically occurs at lower temperatures (slightly above 110°F [43.3°C]) than occurs in warewashing machines (typically from 120 to 140°F [49 to 60°C]). The mechanical action provided by manual scrubbing is less vigorous than the pressurized wash water jets in warewashing machines. This lack of vigor can be compensated for by using potent cleaning agents and providing users with effective scrubbing tools. Manual warewashing often requires overnight presoaking to loosen tough soils.

Sensory aspects of cleaning agents

End users often interpret suds in the wash sink as indication of sufficient cleaning agent available for soil removal. However, depending on the cleaning formula and suspended or solubilized soils, suds could be stable yet the cleaning solutions may not be able to properly clean due to oversaturation of soils, especially fatty soils. In contrast, many ingredients used to formulate cleaning agents are low foaming yet excel at degreasing certain fats. When cleaning formulations are designed for highly turbulent applications such as those of a warewashing machine, low foam is important to prevent spills or malfunction of system pumps. The manufacturer's instructions should specify when to replenish cleaning solutions with new water and fresh cleaning agent.

OPPORTUNITES FOR IMPROVEMENT: NEW SURFACE CLEANING TECHNOLOGIES

Innovation drivers

Three industry pressures drive innovation of cleaning technologies, particularly concentrated products. First, concentrated chemicals require specialty packaging beyond the traditional "bag-in-a-box" or 5-gal (19-liter) pail. Second, concentrated chemicals require safe handling because they are dangerous, and some market segments do not use them unless there is a safe way to handle them. Third is end-use cost. Traditionally, concentrated chemicals require dispensing equipment. Equipment costs money and must be maintained over time. Recent innovations in cleaning agents center around a maintenance-free system that uses recycled materials. Packaging materials are also an area of recent innovation, driving a need for thicker, more durable, and compatible materials to safely store hazardous formulas.

Cleaning devices

Cleaning devices, machines, and robots are key growth areas. Machines or robots that can assist with or lead cleaning activities are often used to reduce labor costs. Replacing or reducing cleaning time is a primary return-on-investment strategy for adopters of cleaning machines or robots. Some innovations include auto scrubbers, electrostatic sprayers, autonomous scrubbers, vacuums, and connected warewashing machines.

Dry cleaning

Some establishments (e.g., bakeries) require reduced moisture approaches to cleaning. Traditional dry cleaning methods include sweeping, scraping, dusting, vacuuming, and mopping. Other dry cleaning methods have become more common in the industry, such as use of alcohol-based cleaning agents and vacuums with high-efficiency particulate air (HEPA) filters. Alcohol-based products are preferred because they dry quickly, whereas HEPA filters better control spread of unwanted contaminants in the air. Innovations used in food manufacturing settings include low-moisture steam, liquified carbon dioxide or bicarbonate blasting, and alkaline powders; however, many of these methods are not practical for use in foodservice establishments.

Dosing and dispensing

Over the past decade, incremental advancements have occurred in equipment for dosing and dispensing cleaning agents. Although these improvements have been beneficial, the majority of useful innovations revolve around modifying existing equipment. Recent innovations include technologies that enable tracking of chemical consumption and compliance with food safety regulations. These technologies can be used to monitor important factors such as the final rinse temperature of a warewashing machine and water consumption of a dispenser and can alert users when cleaning solutions need replacement or when a machine or dispenser is not functioning properly. Smart "connected" chemical dosing and dispensing platforms provide valuable information for supply chain management, compliance monitoring, and predictive analytics.

Coatings and films

Coatings are not a new area of cleaning. Antimicrobial compounds have been embedded in fabrics to control pathogenic microorganisms *(21)*. These technologies are being discussed in the food industry as supplementary sanitation treatments. The objective is to safeguard surfaces and prevent the colonization of pathogenic microorganisms, thereby indirectly protecting surfaces between regular cleanings or antimicrobial treatments. Temporary films such as Silane-Quats have gained attention. These materials are applied and dried onto surfaces, particularly high-touch surfaces. Manufacturers claim that these coatings can last for weeks to months. Some coatings and films can be rejuvenated by adding an antimicrobial agent, whereas others require complete reapplication. However, the adoption of temporary coatings is hindered by the need for frequent reapplication and the level of soil in the environment. Another obstacle to the widespread adoption of coatings and films is the requirement for EPA registration if public health claims are to be made about their efficacy.

Biological cleaning agents

Recently, manufacturers have created cleaning agents containing a cocktail of enzymes or of enzyme-producing bacteria (i.e., probiotic cleaners). The intent is for the enzymes to provide an additive effect to the cleaning agent's cleaning power, replace ingredients in a previous product version, or replace features of older, harsher cleaning agents. Generally, products with enzymes or probiotics are less harsh at the use dilution because many enzymes require a close to neutral pH (6 to 9). However, there are trade-offs and challenges to use of these types of products. First, the manufacture of enzymes and probiotics is costly compared with that of traditional chemical ingredients used in cleaning agents. Enzymes are also sensitive to environmental factors (e.g., high temperature and extreme pH levels), limiting overall formulation and operational use parameters. The duration of their biological activity in the environment is also unclear. These limitations may make these biological agents inappropriate for some food settings where hot water and acid and/or alkaline cleaning agent work best.

Cleaning agents containing naturally derived ingredients are an emerging area. The intent is to replace products that are environmentally unfriendly, toxic, or harsh on skin or surfaces. Naturally derived products may benefit the environment but require the same level of soil removal scrutiny as required for products derived from chemicals. Another area of emergence is replacement of builders with natural ingredients to reduce heavy metal effluents. Production of surfactants with sugars or replacement of harsh solvents with naturally derived solvents are growing areas of chemical manufacturing. Products that provide an environmental or safety benefit are important, but it is equally important to understand that product performance might be reduced, which may require reworking or switching to other cleaning agents for soils that are tough to remove.

CONCLUSIONS

In this article, we provide valuable insights and a call to action for stakeholders involved in preventing the transmission of foodborne illnesses. The diversity of soil types found in foodservice establishments and the lack of standardized cleaning agent performance standards highlight the urgent need to reevaluate surface cleaning practices. Operators must use effective cleaning agents, follow proper procedures, and adhere to best cleaning practices outlined in the Food Code to address this issue. Our main focus is to raise awareness about the significant risks of not implementing proper sanitation practices in foodservice establishments, particularly regarding cleaning agent selection, cleaning tools and procedures, and cleaning compliance across an establishment operation. These areas receive less scrutiny than does, for example, the use of sanitizers on food-contact surfaces.

Our argument underscores the necessity of developing a unified, cost-effective, accurate, and quantitative method for evaluating cleaning products, procedures, and practices, specifically focusing on surface cleaning in foodservice establishments. The high rates of sanitation compliance violation further emphasizes the need for improvement. By fostering collaboration among regulatory agencies, industry representatives, academia, establishment operators, and end users, we have an opportunity to enhance food safety practices in foodservice establishments. To tackle these challenges, we propose that federal agencies such as the EPA, FDA, and CDC join forces with local regulatory authorities to establish partnerships with industry professionals representing foodservice establishments and cleaning product manufacturers. This collaborative working group can address the existing challenges while considering the diverse needs and preferences of all stakeholders. An effective starting point would be the formation of a committee within the Conference for Food Protection tasked with defining and measuring "cleaning" in the Food Code and Food Code Annex, similar to how the disinfection of food-contact surfaces was addressed in the same venue *(15)*.

Any proposed solution must take into account the limitations and resource constraints faced by some stakeholders, particularly small, independent establishment owners, when promoting surface cleaning standards. By considering these factors, we can collectively work toward establishing effective and practical approaches to enhance surface cleaning practices in foodservice establishments.

ACKNOWLEDGMENTS

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of CDC, the Agency for Toxic Substances and Disease Registry, the FDA, the Center for Food Safety and Applied Nutrition, or the EPA. Tajah Blackburn and Kristen Willis are employees of the EPA, and Veronica Moore is an employee of the FDA. Any mention of trade names, manufacturers, or products does not imply an endorsement by the U.S. government, the FDA, or the EPA. The FDA, EPA, and their employees do not endorse any commercial products, services, or enterprises.

The authors would like to thank Amber Rumple, Ph.D., Diversey for her critical review of the manuscript.

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