Chapter 30

Domestic and Indoor Microbiology

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It has been suggested that perhaps 80% or more of all common infections including colds, flu, skin infections, gastroenteritis and diarrhea are acquired by exposure to our environment. Since humans in developed countries spend from 35 to 90% of their time indoors, sources of pathogens can be the air, food or water that enters a home. In addition, humans themselves that acquire an infection outside of the home can subsequently be a source of pathogens within the home. Once inside a home, pathogens can be transferred either via person–person contact, or via person–fomite–person. Other indoor environments including schools, workplaces and hospitals are also reservoirs of human pathogens. In this chapter we identify household and indoor sources of pathogens, and their fate and transport within the indoor environment.

30.1 HOUSEHOLD SOURCES OF PATHOGENS

30.1.1 Air

Microbial airborne pathogens occur as bioaerosols (see Chapter 5) and include bacteria, viruses, molds and spores. Molds are fungi that include species of *Cladosporium*, *Penicillium*, *Aspergillus* and *Alternaria*. Molds are highly prevalent in damp areas of homes. Since molds reproduce via spores that are easily windborne, they can easily enter households via open doors or windows. After landing, mold spores can colonize damp solid surfaces within 72 hours. Once they are established, it is difficult to remove molds, and frequently absorbent materials such as ceiling tiles or carpets need to be replaced. Molds cause a variety of health concerns including nasal stuffiness, eye irrigation, wheezing or skin irrigation. Some individuals have more serious allergies to molds, and high concentrations of molds can result in fever and/or shortness of breath. Threshold levels of molds are unknown and may vary with the type of mold. Health complaints, however, have been associated with concentrations of 2000 CFU m^{-3} of mixed mold populations in air samples (Reynolds, 2006).

House dust mites are microscopic organisms related to spiders and ticks (Figure 30.1). Allergens from dust mite feces contribute significantly to seasonal allergies and asthma. Approximately 20 million Americans are allergic to dust mites, which are ubiquitous and cause serious problems in approximately half of all U.S. homes (Reynolds, 2006). Dust mites feed on dead human skin, and thrive in household dust, bedding and carpeting, particularly in humid areas.

Another important household allergen is endotoxin (Figure 5.15). Endotoxin is derived from lipopolysaccharide contained within the outer cell wall of Gram-negative bacteria, and can cause a variety of health ailments. Most adverse health effects associated with endotoxin have been associated with occupational exposures such as grain houses, cotton dust or composting

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FIGURE 30.1 A dust mite.

plants. However, household dusts are also known to contain endotoxin, and the potential risks associated with routine, low-level exposures in common indoor environments are unknown (Reynolds, 2006).

Infectious pathogens, including viruses and bacteria, can also be found in household air. For example, influenza, colds and even chicken pox and tuberculosis are transmitted within households. In any given year up to 50 million Americans contract "the flu" and an average of 20,000 to 40,000 die each year. Overcrowded conditions and poor air circulation exacerbate the spread of infectious agents. Exposure to such pathogens can occur directly from humans through a sneeze or cough, or indirectly due to showering or toilet flushing. Home humidifiers are frequently a breeding ground for bacteria, protozoa or fungi, and have led to the use of the term "humidifier fever." Symptoms are similar to a short-term flu-like illness. Hot water systems and air conditioning units have been implicated in outbreaks of Legionnaires' disease and Pontiac fever caused by the bacterium *Legionella pneumophila*.

30.1.2 Food

It is estimated that there are about 47 million cases of foodborne illness every year in the United States (CDC, 2013). All types of foods can be associated with foodborne illness (Figure 30.2). Many common foods brought into homes routinely contain human pathogenic microbes including: *Salmonella*; *Campylobacter*; *Listeria monocytogenes*; *Staphylococcus aureus*; and *E. coli* O157:H7 (Chapter 22). *Salmonella* is often found in poultry and seafood, often in association with *Campylobacter*. Reng *et al.* (2007) detected *Salmonella*, *Campylobacter* or *Arcobacter* in 80% of 54 samples of duck. *Listeria* can be found in a variety of foods including raw milk, cheeses,

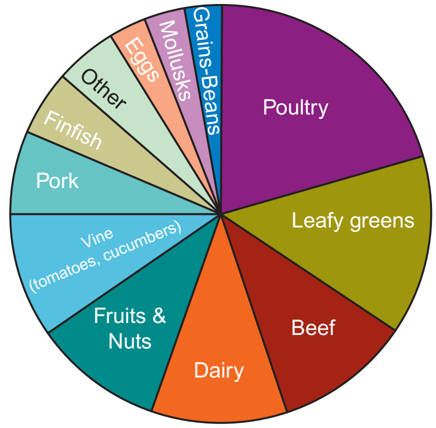

FIGURE 30.2 Causes of illness in outbreaks from single food commodities in the United States, 1998–2010.

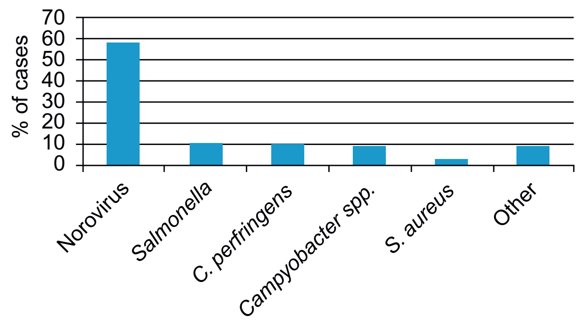

FIGURE 30.3 Top pathogens contributing to foodborne disease in the United States, 2011 (CDC, 2013). Created by C.P. Gerba.

ice cream, raw vegetables, poultry and smoked fish. This organism causes a general group of disorders including meningitis and encephalitis. Of particular concern is its ability to grow at temperatures as low as 3°C, permitting multiplication even in refrigerated foods. *Staphylococcus aureus*, besides causing skin infections, can also cause staphylococcal food poisoning due to enterotoxins produced by some strains. *S. aureus* is more prevalent in foods that require excessive handling, and that are kept at slightly elevated temperatures after preparation. *E. coli* O157-H7, an enterohemorrhagic strain of *E. coli*, causes the acute disease hemorrhagic colitis, which can even be fatal. This strain of *E. coli* has been associated with undercooked hamburger. Outbreaks are also associated with produce such as lettuce and spinach which were contaminated before harvest of during handling (Delaquis *et al.*, 2007). Perfringens food poisoning is the term used to describe the common foodborne illness caused by *Clostridium perfringens*. Stored meat products are most commonly associated with *C. perfringens*. However, the major cause of most outbreaks are the human noroviruses, probably resulting from contamination of foods from handling by infected persons, from water or from other environmental sources of contamination (Figure 30.3).

All of these food products can result in human infections within households via two mechanisms: contamination of human hands and fomites during food preparation; and consumption of raw or undercooked foodstuffs. Contamination of fomites can subsequently result in further contamination of other fomite surfaces, particularly in the kitchen (Section 30.3).

30.1.3 Water

In developed countries, water is treated at public utilities and supplied to homes via utility distribution systems. Although water is disinfected prior to entering distribution systems, as the treated water travels through the distribution pipe system and into the home, the microbial water quality degrades and bacterial growth and regrowth can occur (see Chapter 28). Such microbial growth results in the development of biofilms, which further protects microbes (see Section 6.2.4.1). Thus, the number of heterotrophic bacteria (heterotrophic plate counts or HPC) in drinking water has been used as an estimate of the microbial water quality drinking water. Generally, a high HPC is equated with poor microbial water quality. The numbers of HPC would be expected to be elevated if surface waters are not adequately treated, or if a cross contamination event with a sewer line has occurred. However, it has been known for a long time that heterotrophic bacteria grow in distribution systems even in the presence of chlorine (Case Study 30.1).

Water distribution systems are clearly a source of microorganisms that humans are exposed to on a daily basis, but they appear to be no threat to normal healthy individuals. General groups of bacteria capable of specific biochemical transformations such as sulfate reduction and nitrification have been identified in tap water (Pepper *et al.*, 2004). More recently, both cultural and molecular methods were used for microbial community analyses of drinking water from four United States cities (Case Study 30.2). Of organisms that grow in the distribution system *Legionella pneumophila* and *Acanthamoeba* spp. are the only ones that are commonly associated with illness. *Legionella* is associated with respiratory illnesses from exposure to warm water via showers, hot tubs, air humidifiers and water fountains.

Acanthamoeba infections are associated with persons who use tap water to wet their contact lenses. Both of these organisms grow in biofilms, and *Legionella* can actually grow inside *Acanthamoeba* amoeba, which protects it from the action of chlorine.

30.2 FOMITES: ROLE IN DISEASE SPREAD

In most discussions of disease spread, inanimate objects or fomites have been overlooked as agents of transmission. However, we continuously come into contact with a wide range of surfaces that may serve as vehicles or reservoirs of pathogenic microorganisms. Fomites can include doorknobs, sink taps, cutting boards, computer keyboards and of course the toilet seat. Because personal contact among nonrelated adults is limited in most cultures, fomites are believed to play a significant role in the transmission of some pathogens. What is often perceived to be person-to-person spread is actually person–fomite–person spread. For example, rhinovirus, the cause of the common cold, is readily transmitted by contact with virus-contaminated fingers brought to the nose or eyes (Figure 30.4) (Hendley *et al.*, 1973). Fomites can also result in cross contamination from foods when raw meat contaminates a cutting board or a food handler, and then other foods such as spinach are prepared on the same board, and become contaminated and consumed raw. In addition, studies conducted in hospitals have demonstrated that fomites play a role in hospital or nosocomial infections.

Case Study 30.1 Heterotrophic Plate Count Bacteria in Source Waters and Household Taps

The concentrations of heterotrophic plate count (HPC) within water reaching consumer taps and from the water sources used by a major water utility were evaluated. The average HPC concentration in source waters ranged from 38 to 502 CFU/ml. The concentrations of HPC in a kitchen tap and other water containers are shown in Table 30.1. HPC in bathroom tap water are shown in Table 30.2. Clearly HPC in municipal waters were greater than the number of HPC in source waters, illustrating that bacterial growth had occurred. These data illustrate that water distribution systems contain living microbial communities that enter households.

TABLE 30.1 Heterotrophic Plate Counts from Seven Different Households[a]

	HPC (CFU/ml)			
	Kitchen Tap	Commercial Bottled Water	Sports Bottle	POU Device[b]
Range	$4-7 \times 10^7$	0–90,000	240–34,000	$4-1 \times 10^7$
Mean	399	1750	17,000	4000

Modified from Pepper et al. (2004).
[a]*Assayed on trypticase soy broth at room temperature for 5 days.*
[b]*POU, point of use device mounted on the tap. These devices usually consist of activated charcoal to remove taste and odor.*

TABLE 30.2 Heterotrophic Plate Count Bacteria in Bathroom Tap Water

	Overnight HPC (CFU/ml)			
	Before Flush		After Flush	
	House 1	House 2	House 1	House 2
Mean	2.4×10^3	2.4×10^3	1.5×10^2	1.4×10^2
S.D.	1.6×10^3	4.3×10^3	1.0×0^2	1.4×10^2

Modified from Pepper *et al.* (2004).

Case Study 30.2 Water Distribution Systems as Living Ecosystems: Impact on Taste and Odor

Six waters from different U.S. cities with known diverse taste and odor (TO) evaluations were selected for additional microbial characterization. All waters were subjected to microbial and cultural analyses, and four of the waters were further analyzed by cloning and sequencing of community 16S rRNA. The purpose of the study was to evaluate water distribution systems as living ecosystems, and the impact of these ecosystems on TO. All waters had total bacterial counts of at least 10^3 per ml. The water with lowest TO ranking had 10^6 total counts per ml. Community DNA sequence analysis identified diverse bacterial communities representing five different phyla and over 40 genera. Included in this diversity were heterotrophic and autotrophic species that were both aerobic and anaerobic. In addition, numerous opportunistic and nosocomial pathogens were identified (Table 30.3). Additionally, waters with the lowest TO evaluations contained significant sulfide concentrations, as well as bacteria associated with both the oxidation and reduction of inorganic sulfur compounds. Low redox conditions could have resulted in the reduced sulfur compounds and concomitant TO-related problems, and an increase in redox could help alleviate these problems. Overall, data show that water distribution systems contain living ecosystems that evolve based on specific environments within particular distribution systems that impact water TO.

From Scott and Pepper (2010).

Good hygiene practices have been shown to significantly reduce fomite transmission of pathogens. These practices include hand washing, use of hand sanitizers, cleaning and use of disinfectants. The importance of hand hygiene was demonstrated more than 100 years ago by Dr. Ignaz Semmelweis, an Austrian–Hungarian physician, who in 1847 discovered that the incidence of child bed fever (infections of the mother after delivering) could be drastically reduced by hand washing. Numerous studies have demonstrated that 30 to 50% reduction of illness can occur by providing adequate hand washing facilities and by encouraging good hand washing practices (Van Curtis and Cairncross, 2003). Similar results have been obtained with alcohol gel sanitizers (White *et al.*, 2003; Vessey *et al.*, 2007).

Changes in lifestyles in the twenty-first century have increased our interactions with our indoor environments. This has increased the potential for fomite transmission of pathogens. For example, in the developed world most of us work in homes or offices, and spend most of our day indoors. We work in ever-larger buildings; vacation in larger hotels, resorts and cruise ships; visit stadiums of increasing size; visit health care centers rather than physicians' offices; fly in ever larger planes; and shop in large indoor shopping malls and super stores. All of these factors result in the increased sharing of fomites. Noroviruses provide an example of a virus easily spread by fomites that has resulted in the cancellation of vacation cruises and the closure of schools, hotels, gambling casinos, summer camps and hospital emergency rooms. This has created a need for a better understanding of pathogen spread by fomites and effective means for their control.

Enteric, respiratory and dermal pathogens have the greatest potential to be spread by fomites because they are released into the environment in large numbers via infected individuals. Also, enteric bacteria have the ability to grow in foods as well as some fomites such as sponges. The low number of viruses needed to cause infection makes fomite transmission more likely than for bacteria, which usually require contact with larger numbers of organisms to have a significant probability of infection (Chapter 22). Even blood-borne viruses can be spread by fomites. For example, an outbreak of hepatitis B virus was traced to computer cards, which infected small cuts when handled. Plantar warts, for which papovavirus is responsible, are generally contracted by walking barefoot in swimming areas, gyms, barracks or other public places. Some protozoa, such as *Giardia* and *Cryptosporidium*, may also be spread by this route, especially among young children.

30.2.1 Occurrence of Pathogens on Fomites

Fomites may become contaminated with pathogens by direct contact with bodily excretions/secretions (mucus, salvia, blood, feces). Alternatively, such fluids may be transferred from soiled hands to fomites, or airborne organisms may impinge or settle onto fomite surfaces. Fomites may also serve as a site for the replication of a pathogen, as in the case of enteric bacteria in household sponges or dishcloths. Until the development of molecular methods, such as PCR, data on the occurrence of pathogens on fomites were very limited because of the difficulty and cost associated with the isolation of pathogens

TABLE 30.3 Opportunistic and Nosocomial Pathogens Identified within Municipal Tap Water Collected from Four U.S. Cities

Genus/Species[a]	General Description
Microbacterium sp.	Aerobic heterotrophic bacterium found in soil and other environments. Some species are opportunistic pathogens.
Mycobacterium sp.	Aerobic heterotrophic bacterium associated with a variety of environments including household dust, drinking water and clinical specimens. Some species are pathogenic to humans.
Sphingobacterium multivorum	Aerobic heterotroph found in many environments including soil and clinical specimens. Opportunistic human pathogen.
Brevundimonas dimunitia	Aerobic, chemoorganotrophic to oligotrophic. Typically occupy aquatic habitats. Uncommon noscomial pathogen.
Methylobacterium sp.	Aerobic chemoheterotrophic and facultatively methylotrophic. Frequently airborne, found in dust and other environments such as freshwater. Some are opportunistic pathogens.
Acinetobacter johnsonii	Aerobic heterotroph found in a wide variety of environments. Opportunistic nosocomial pathogen.
Acinetobacter junii	Aerobic heterotroph. Opportunistic nosocomial pathogen.
Pseudomonas mendocina	Some strains reduce elemental sulfur. Very rarely found as opportunistic human pathogen.

Modified from Scott and Pepper (2010).
[a]*All clones had a sequence match identity of at least 98% as defined by Ribosomal Database Project 11 (Cole et al., 2007; Wang et al., 2007).*

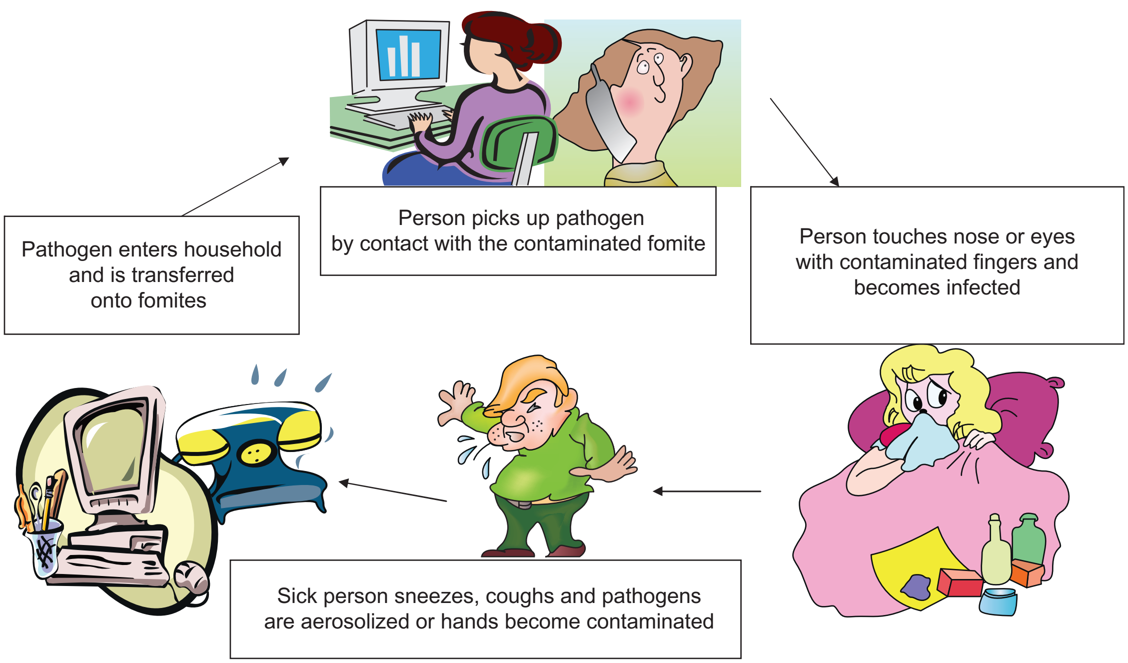

FIGURE 30.4 Role of fomites in respiratory disease transmission. Courtesy A. Moghe and C.P. Gerba.

from fomites. However, recent studies have shown that pathogens can rapidly contaminate the indoor environment. For example, it was found that in households with two children with influenza infections, influenza virus could be found on more than 50% of common fomites such as phones, TV remotes, faucets and doorknobs (Boone and Gerba, 2005). In a study of offices, parainfluenza could be isolated from one-third of all offices tested during the fall throughout the United States (Boone and Gerba, 2010). Rhinovirus, a major cause of the common cold, has been detected on 40 to 90% of the hands of adults with colds, and from 6 to 25% of selected fomites in rooms inhabited by persons with colds. During outbreaks, norovirus has been detected on toilet flush handles, gambling chips and doorknobs. Enteric bacteria such as *Salmonella* have been detected in likely places such as

Information Box 30.1 General Categories of Fomites

- **Reservoirs**—such as toilets, sinks, drains, clothing. These generally have high levels of contamination, including enteric bacteria, and have the potential environment for bacterial multiplication (Figure 30.5).
- **Reservoirs–disseminators**—cleaning tools such as sponges, dish cloths, vacuum cleaners and mops, on which there can be high levels of contamination, and the potential exists for bacterial multiplication. However, in addition, the potential exists for direct transfer of this contamination to surfaces whenever these items are used (Figure 30.6).
- **Hand and food contact surfaces**—such as kitchen counters, cutting boards, faucets, handles, laundry or fabrics on which there may be lower levels of contamination, but still the potential for the presence of pathogens, together with the constant potential for cross contamination to other crucial surfaces such as high-risk foods that are eaten raw or the hands (Scott, 1999).

FIGURE 30.5 Locations in the household where bacteria can grow. Courtesy C.P. Gerba.

FIGURE 30.6 Objects involved in transfer of microorganisms in the household. Courtesy C.P. Gerba.

toilets, but also in household kitchen sinks, diaper hampers, vacuum cleaner dust, and cleaning tools, such as sponges, dishcloths and mops. Fomite contamination has been classified into three general categories of sites or surfaces on which the risk of contamination or cross contamination is greatest (Scott *et al*., 1982) (Information Box 30.1).

Coliform bacteria in households are found in high concentration on kitchen sponges, and in sink areas relative to bathroom areas, which are more commonly associated with this group of bacteria (Figure 30.7). Enteric bacteria are brought into the home kitchen on raw meat and vegetables, where they can grow to large numbers in moist environments where food is available. This includes kitchen fomites and even cleaning tools—enteric bacteria can be spread around a home during normal cleaning of surfaces.

Public toilets have been shown epidemiologically to be responsible for outbreaks of *Shigella*, *Salmonella*, hepatitis A virus and norovirus. It has been demonstrated that viruses and bacteria are ejected to some degree when toilets are flushed, allowing for contamination of restroom areas adjacent to the toilet (Gerba *et al*., 1975). The most common areas where fecal coliform bacteria are isolated in public restrooms include the floor, taps and sink drains (Figure 30.8), suggesting that these areas are more likely to be contaminated by pathogens originating from feces. Recent studies using pyrosequencing indicate that most bacteria in indoor environments originate from the human body (Figures 30.9 and 30.10).

30.2.2 Persistence of Pathogens on Fomites

The persistence of a pathogen on a fomite is dependent on a number of factors (Table 30.4). The rate of drying and temperature are the most important factors controlling survival. For most organisms, inactivation or death occurs most rapidly during the drying of the liquid in which it

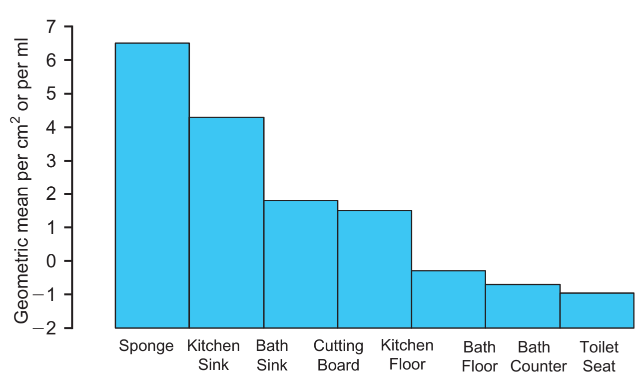

FIGURE 30.7 Concentration of coliform bacteria in the home. After Rusin *et al*. (1998).

was suspended. This is largely determined by the relative humidity of the air. The lower the relative humidity, the more rapid the drying takes place. Once drying is complete, the rate of organism die-off usually decreases (Figure 30.11). Some organisms survive better at lower relative humidity and others at high relative humidity (Table 30.5). In most indoor buildings with air handing systems, the relative humidity usually ranges from 40 to 60%. It is usually less in the winter because of indoor heating, which may favor the survival of some respiratory viruses such as influenza. Suspending media can also influence survival, for example rhinovirus in tryptose phosphate broth did not survive as well as in nasal secretions (Sattar *et al.*, 2000). The nature of the virus and perhaps the route of transmission also play a role in the survival of viruses on fomites. While the survival of common respiratory viruses is usually a matter of hours to days, that of enteric viruses can be measured in days to weeks (Figures 30.12 and 30.13). The type of surface also may play a role, but a clear answer is not currently available because the efficient recovery of the organism from the different surfaces has not yet been determined.

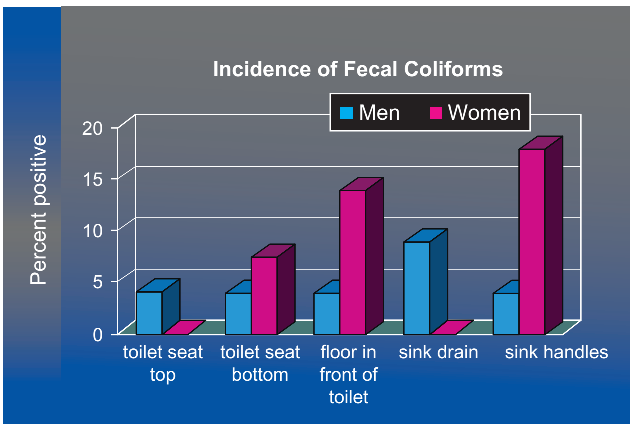

FIGURE 30.8 Frequency of isolation of fecal coliform bacteria at different locations in public restrooms. Courtesy C.P. Gerba.

30.3 TRANSFER OF PATHOGENS

Transfer of pathogens from an infected host to a fomite and pathogen transfer to a susceptible host are also important in understanding transmission. Clean hands can readily become contaminated when objects or surfaces are touched or handled. The reverse is also true. Individuals with rhinovirus colds were shown to deposit infectious rhinovirus particles on objects that they touch (Sattar and Springthorpe, 1996). The virus could also be recovered from the fingertips of volunteers who handled objects such as doorknobs previously touched by virus contaminated hands. Further studies using volunteers have demonstrated that placement of rotavirus-contaminated hands in the mouth or rhinovirus-contaminated hands in the nose also results in transmission of these viruses. Children frequently bring objects to their mouths. In fact, children less than 2 years of age have been observed to

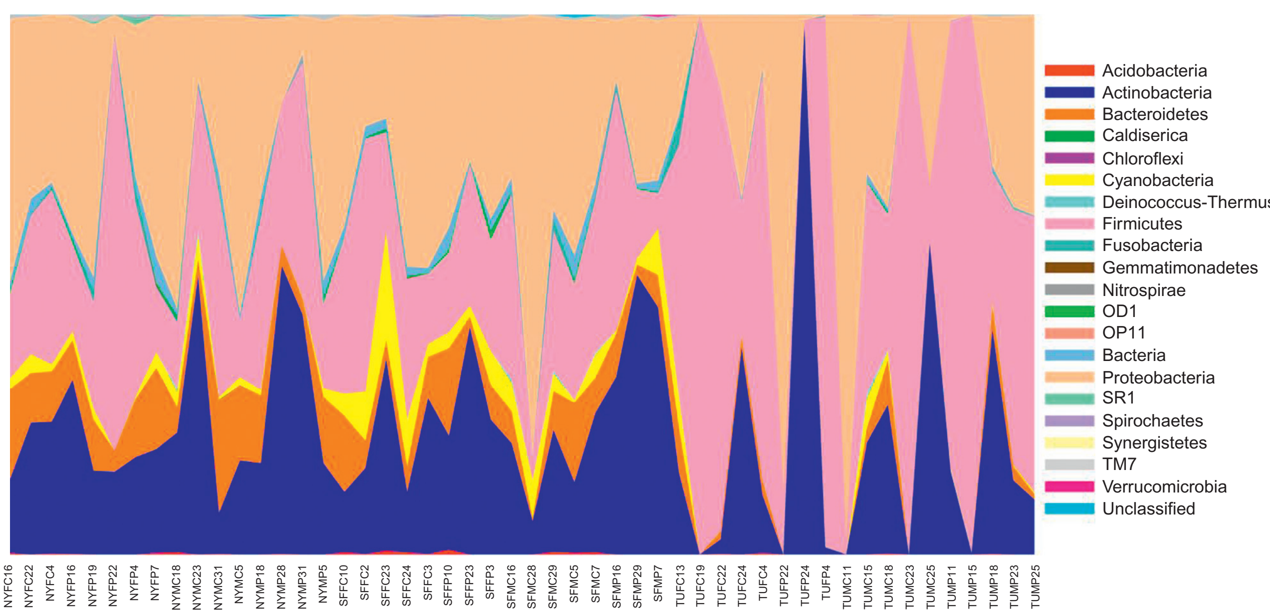

FIGURE 30.9 Relative abundance of bacterial divisions across samples. The abundances of various bacterial divisions (see color legend) in the 54 samples were based on multiplexed pyrosequencing of 16S rRNA gene sequences. The codes for each sample are presented along the X-axis and indicate the city (NY = New York, SF = San Francisco, TU = Tucson), gender of the office occupant (F = Female, M = Male) and site within the office from which the sample (C = Chair, P = Phone) was obtained, followed by sample number (Hewitt *et al.*, 2012).

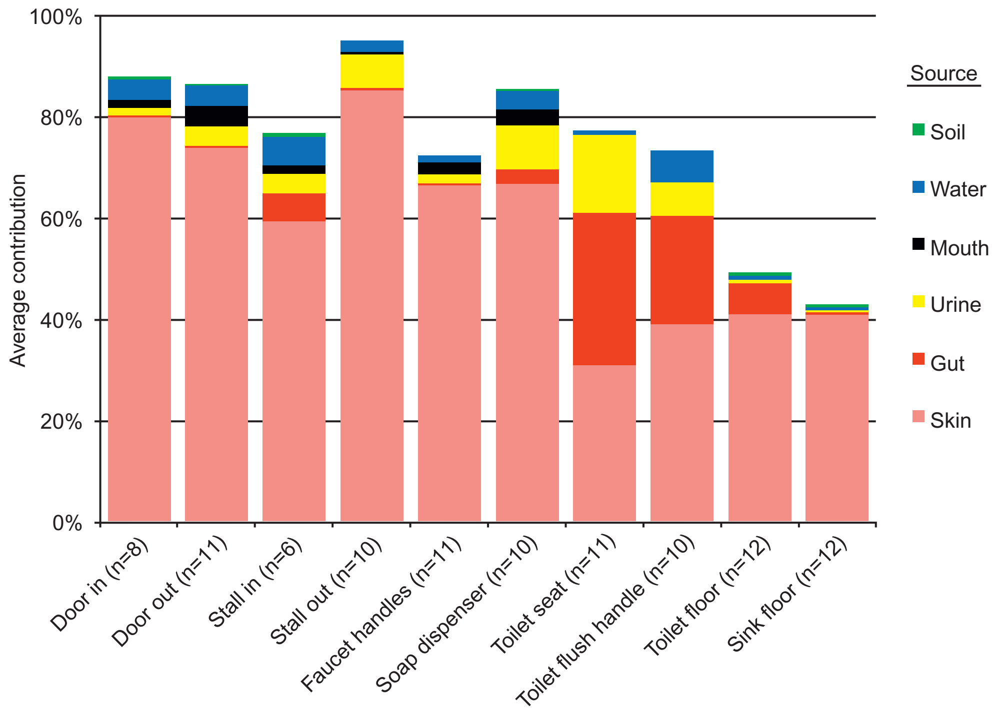

FIGURE 30.10 The average contributions of different sources to the surface-associated bacterial communities in 12 public restrooms. (The "unknown" source is not shown but would bring the total of each sample up to 100%.) (Flores *et al*., 2011.)

TABLE 30.4 Environmental Factors Affecting the Survival of Microorganisms on Fomites

Factor	Primary Effect	Pathogen Example of Extreme Resistance
Temperature	Denaturization of proteins and nucleic acides; generally longer survival at lower temperatures	Bacterial spore formers Parvovirus
Solar irradiation	UV light causes cross-links along the nucleotides	Bacterial spore formers dsDNA viruses
Presence of organic matter	Can stabilize/destabilize proteins; protects against irradiation; neutralizes antagonistic substances; can serve as a nutrient source	
Interfaces	Greater stability at solid—water interfaces; less stability at air—water interfaces	Depends on nature of outer surface and resistance to denaturization
Dehydration	Loss of water causes denaturization of proteins	Spores
Relative humidity	Effects stability of proteins	Humidity range of least stability depends upon the organism

bring objects or their hands to their mouth an average of 81 times per hour (Tulv *et al*., 2002). Studies have shown that the degree of virus transfer to the hand is related to:

- Age—an increase in the age of the individual reduces the relative amounts transferred probably because of less moisture in the skin
- The amount of pressure applied
- The application of friction which substantially increases the amount of virus transferred

The degree of transfer of any organism will depend on the nature and type of organism, nature of the surface and the amount of moisture (Figure 30.14). Higher bacterial transfer rates from fomite to the hand have been observed with hard nonporous surfaces (phone receiver, faucet) than with porous surfaces (clothing, sponges) (Rusin

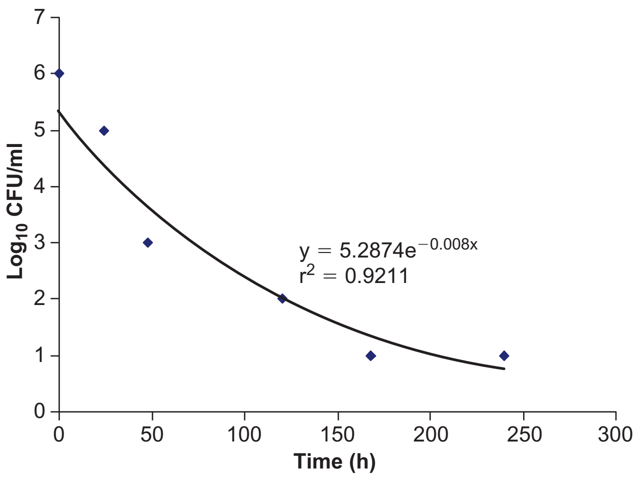

FIGURE 30.11 Survival of methicillin-resistant *Staphylococcus aureus* (MRSA) on stainless steel. Courtesy A. Moghe and C.P. Gerba.

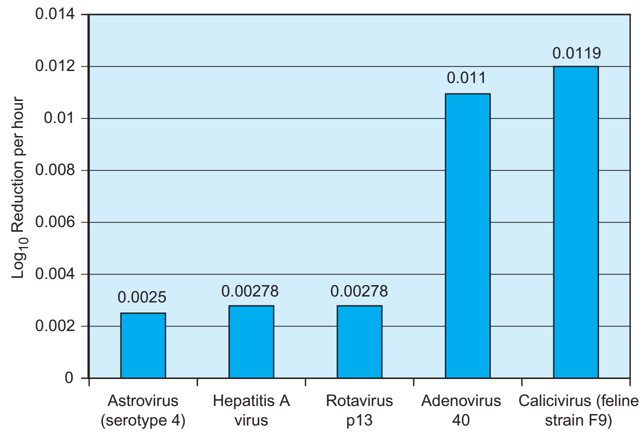

FIGURE 30.13 Inactivation rates of enteric viruses on fomites. From Boone and Gerba (2007). Reprinted with permission from the American Society for Microbiology.

TABLE 30.5 Examples of the Effects of Relative Humidity (RH) on Stability of Viruses

RH Range	Stability	Virus
>75	High	Vaccinia, reovirus
	Low	Adenovirus, poliovirus, foot and mouth disease, parainfluenza, measles
40−75%	High	Vaccinia, influenza
	Moderate	Poliovirus, MS 2 coliphage
	Low	Reovirus, T3 coliphage
<40%	High	Influenza, vaccinia
	Moderate	Reovirus, measles
	Low	Parainfluenza, T3 coliphage, poliovirus, adenovirus, foot and mouth disease

Selected from Spendlove and Fannin (1982).

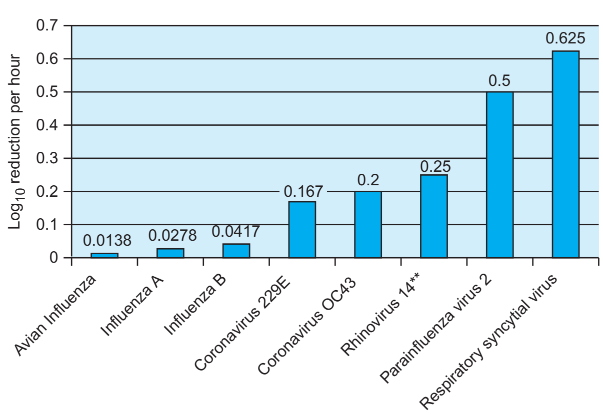

FIGURE 30.12 Inactivation rates of common respiratory viruses on fomites. From Boone and Gerba (2007). Reprinted with permission from the American Society for Microbiology.

et al., 2002). Although, greater numbers of bacteria were present in the wet sponge, the overall efficacy of transfer was less than from a stainless steel surface. When the same volunteers placed their fingers to their lips, 34 to 41% of the bacteria were transferred to their mouths depending on the type of bacteria. While such studies are useful for the demonstration of the potential role fomites play in disease transmission, they can also be used in risk assessment models to estimate the probability of disease transmission by fomites in a particular environment and the impact of interventions (Figure 30.15).

30.4 QUESTIONS AND PROBLEMS

1. Determine the time in hours for influenza A and hepatitis A virus to decrease in titer by 99% on a fomite.
2. Why would influenza virus be more likely to be transmitted in the winter by fomites than poliovirus?
3. What conditions would favor the growth of bacteria in/on fomites?
4. Determine the number of *Salmonella* a person will ingest if they touch a cutting board contaminated with 100,000 *Salmonella* per square centimeter. Assume that a fingertip has an area of one square centimeter and that only one finger touches the surface. List all your assumptions in a table. Using the risk model presented in Chapter 24 determine the probability of the individual becoming infected.
5. Look at the classroom you are sitting in and list three objects that would most likely become contaminated by a person infected with norovirus. Give your reasons why. Which object would have the greatest efficiency for transfer of a virus onto your hand?

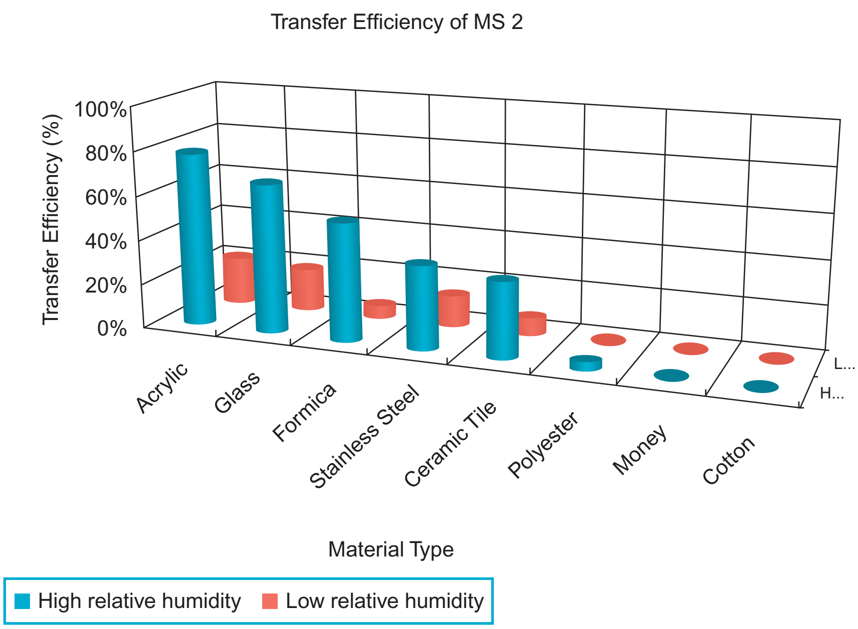

FIGURE 30.14 Transfer efficiency of coliphage MS 2 from various fomites to the hand. Courtesy G. Lopez.

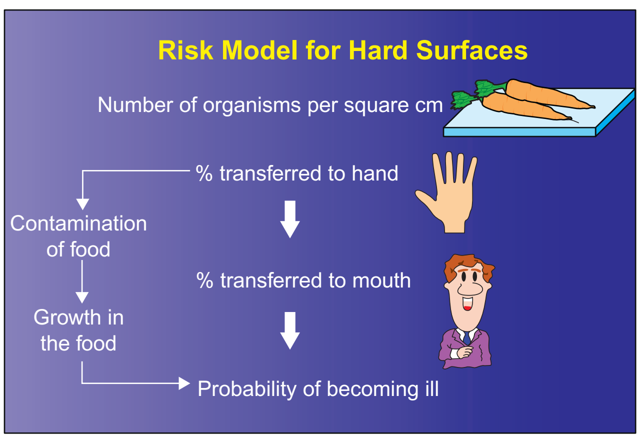

FIGURE 30.15 Risk model assessing pathogen transmission by hard surfaces. Courtesy C.P. Gerba.

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