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Spread of infectious diseases by microorganisms present in fomites

Aakriti Guleria *

School of Health Sciences, Abhilashi University, Chailchowk, Mandi, H.P. (175045) India.

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Abstract

Fomites, inanimate objects that can carry infectious agents, play a critical role in the spread of infectious diseases. Despite advances in sanitation and hygiene practices, fomites remain a significant vector for the transmission of various pathogens, particularly in healthcare settings and densely populated environments. This paper reviews the mechanisms by which microorganisms are transmitted through fomites, the types of diseases commonly spread in this way and the factors that influence fomite-based transmission. Strategies for mitigating the risk of fomite-based disease spread are also discussed, highlighting the importance of targeted hygiene interventions, material design and environmental decontamination.

Keywords: Microorganisms; Fomites; Infections; Diseases; Contamination; Strategies

1. Introduction

The spread of infectious diseases remains a major global health concern, especially in densely populated environments such as hospitals, schools and public transport systems. One of the key, often overlooked, pathways for the transmission of pathogens is through fomites—non-living objects or surfaces that can become contaminated with infectious microorganisms and act as vehicles for disease spread. Fomites include everyday items such as doorknobs, clothing, kitchen utensils and medical equipment. Their role in disease transmission is particularly significant in healthcare settings, where the risk of cross-contamination is high and where pathogens like Staphylococcus aureus or drug-resistant organisms such as methicillin-resistant Staphylococcus aureus (MRSA) frequently persist on surfaces [1-3].

Pathogens can be transferred to fomites through respiratory droplets, skin contact or bodily fluids. Once deposited on these surfaces, microorganisms can survive for extended periods, with the ability to infect new hosts when individuals come into contact with these contaminated objects and transfer the microorganisms to mucous membranes or open skin wounds. The survival time of microorganisms on fomites depends on several factors, including the type of pathogen, environmental conditions and the material of the surface. For instance, viruses like SARS-CoV-2, responsible for COVID-19, have been shown to survive on plastic and stainless steel surfaces for up to 72 hours.

The role of fomites in disease transmission became especially evident during the COVID-19 pandemic, underscoring the need to better understand how environmental contamination contributes to disease spread. This paper will explore the mechanisms by which microorganisms are transmitted via fomites, identify the infectious diseases commonly spread this way and examine the factors that influence fomite-based transmission, such as pathogen characteristics and environmental conditions. Additionally, strategies for preventing fomite-mediated transmission, including improved hand hygiene and enhanced surface cleaning protocols, will be discussed [4,5].

* Corresponding author: Aakriti Guleria

2. Microbial Contamination of Fomites

Fomites, as carriers of infectious agents, serve as a crucial medium for the indirect transmission of diseases, particularly in environments where human interaction with surfaces is frequent. Microbial contamination of fomites can occur when pathogens are deposited on surfaces through human contact, respiratory droplets or environmental exposure. Various microorganisms, including bacteria, viruses, fungi and parasites, have been shown to survive on fomites for extended periods, depending on environmental factors and the nature of the surface itself. Fomites serve as a significant reservoir for various types of microorganisms, including bacteria, viruses, fungi and parasites. These pathogens can remain viable on different surfaces for varying lengths of time, depending on the material and environmental conditions. Understanding the types of microorganisms commonly found on fomites is essential for developing effective strategies to control their transmission and reduce the spread of infectious diseases [6,7]. Types of Microorganisms Commonly Found on Fomites are as under:

2.1. Bacteria

Bacteria are among the most common microorganisms found on fomites, particularly in healthcare settings, public spaces and households. Several pathogenic bacteria can persist on surfaces for long periods and contribute to the transmission of diseases.

- ***Staphylococcus aureus***: One of the most prevalent bacterial pathogens found on fomites, *S. aureus* is responsible for a range of infections, from mild skin infections to more severe conditions like pneumonia and sepsis. Methicillin-resistant *Staphylococcus aureus* (MRSA) is of particular concern in hospitals, where it can persist on surfaces like bed rails, medical instruments and healthcare workers' uniforms, posing a serious risk to immune compromised patients. MRSA has been shown to survive on dry surfaces for days to weeks.
- ***Escherichia coli***: Commonly found on fomites in both healthcare and non-healthcare settings, *E. coli* can lead to gastrointestinal infections, especially if it contaminates food preparation areas or utensils. In schools, public restrooms and other communal areas, *E. coli* can persist on surfaces like doorknobs, desks and sinks, increasing the risk of transmission.
- ***Pseudomonas aeruginosa***: This bacterium is another pathogen frequently found in healthcare settings. It can survive on various fomites, including medical equipment, catheters and sinks and is associated with infections in immune compromised individuals. Due to its ability to form biofilms, *P. aeruginosa* can persist in moist environments for extended periods.

2.2. Viruses

Viruses are also commonly found on fomites, particularly respiratory and gastrointestinal viruses. These pathogens can survive on surfaces for hours to days, depending on environmental conditions and surface material.

SARS-CoV-2 (Coronavirus): The COVID-19 pandemic highlighted the significance of fomites in viral transmission. Studies have shown that SARS-CoV-2, the virus responsible for COVID-19, can survive on surfaces such as plastic and stainless steel for up to 72 hours. This made surface disinfection a crucial public health measure to reduce transmission.

Influenza Virus: The influenza virus can remain viable on nonporous surfaces like metal and plastic for up to 48 hours. Contaminated fomites, such as elevator buttons and phones, can serve as a medium for spreading the virus during flu season, particularly in high-traffic public spaces.

Norovirus: A leading cause of viral gastroenteritis, norovirus can survive on fomites for several days to weeks. It is highly contagious and fomite transmission is a significant factor in outbreaks in places like schools, cruise ships and nursing homes.

2.3. Fungi

Fungal pathogens are frequently found on fomites, particularly in moist environments such as public showers, locker rooms and kitchens. Some fungi are harmless, but others can cause infections, particularly in immune compromised individuals.

- ***Candida*** Species: These fungi are commonly found on fomites in healthcare settings and can cause infections in patients, especially those with weakened immune systems. *Candida* can survive on surfaces such as medical devices, patient furniture and healthcare workers' hands, contributing to the spread of hospital-acquired infections (HAIs).

- ***Aspergillus*** Species: Found in soil and dust, *Aspergillus* species can survive on surfaces like air conditioning ducts and windowsills. In healthcare environments, *Aspergillus* contamination can lead to fungal infections in patients with weakened immune systems, particularly those in intensive care units (ICUs).

2.4. Parasites

Although less commonly transmitted through fomites compared to bacteria and viruses, certain parasites can also be spread through contaminated surfaces, particularly in environments with poor sanitation.

- ***Giardia lamblia***: This protozoan parasite is commonly transmitted through contaminated water but can also spread via fomites in unsanitary conditions. In areas with inadequate water treatment or poor hygiene, *Giardia* can survive on surfaces like toys, utensils and bathroom fixtures, leading to outbreaks of gastrointestinal illness.
- ***Enterobius vermicularis*** (Pinworm): Pinworm eggs can survive on fomites such as clothing, bedding and furniture for several days. In environments like daycare centers and schools, children can easily become infected through contact with contaminated surfaces.

Fomites play a significant role in the transmission of various types of microorganisms, including bacteria, viruses, fungi and parasites. The persistence of these pathogens on surfaces underscores the importance of regular disinfection, proper hand hygiene and environmental controls, especially in high-risk settings such as hospitals, schools and public transportation systems. Understanding the characteristics of microorganisms that thrive on fomites allows for more targeted interventions to prevent disease transmission.

3. Factors Influencing Microbial Survival on Fomites

The survival of microorganisms on fomites is influenced by a range of environmental, physical and biological factors. These factors affect the viability of bacteria, viruses, fungi and parasites on surfaces and their ability to infect new hosts [8-10]. Understanding these factors is essential for implementing effective hygiene and disinfection protocols in healthcare, public and household environments.

3.1. Surface Material

The type of surface plays a crucial role in determining how long microorganisms can survive on fomites. Non-porous surfaces, such as plastic, metal and glass, tend to support microbial survival longer than porous materials like fabrics or wood.

- Non-Porous Surfaces: Microorganisms such as *Staphylococcus aureus*, *Escherichia coli* and SARS-CoV-2 can survive on non-porous surfaces for hours to days. A study found that SARS-CoV-2, the virus responsible for COVID-19, remained viable on plastic and stainless steel for up to 72 hours, whereas it survived for shorter periods on more porous surfaces like cardboard. These surfaces tend to retain moisture longer, which helps microorganisms survive.
- Porous Surfaces: Porous materials, such as fabric and paper, generally allow microorganisms to desiccate more quickly, reducing their survival time. However, pathogens like *Staphylococcus aureus* can still survive for extended periods on fabric, which has implications for contamination through clothing and upholstery in healthcare and public environments.

3.2. Humidity and Temperature

Environmental conditions, particularly relative humidity and temperature, are critical factors that influence microbial survival on fomites.

- Humidity: High humidity levels tend to prolong the survival of many microorganisms on fomites by preventing desiccation. Viruses like influenza survive longer at low humidity levels (20-30%) but are rapidly inactivated at higher humidity. Bacteria, such as *Escherichia coli* and *Pseudomonas aeruginosa*, also tend to persist in environments with higher moisture levels, particularly in bathrooms and kitchens, which are prone to frequent contamination.
- Temperature: Microbial survival is inversely related to temperature. Lower temperatures generally prolong the viability of microorganisms, while higher temperatures accelerate their death. Studies show that bacteria and viruses survive longer on fomites at cooler temperatures (e.g., below 20°C). For example, the SARS-CoV-2 virus survives for longer periods at temperatures below 20°C compared to warmer conditions. Similarly,

Staphylococcus aureus persists better at lower temperatures, making cool hospital environments and refrigeration zones more susceptible to contamination.

3.3. Presence of Organic Matter

The presence of organic material, such as skin cells, bodily fluids, food particles or dust, on fomites can provide nutrients for microorganisms, promoting their survival.

- Skin Cells and Body Fluids: Fomites that come into direct contact with human skin, such as towels, bed linens and clothing, often carry organic material that provides a nutrient-rich environment for microorganisms like *Staphylococcus aureus* and *Candida* species. In hospitals, surfaces contaminated with blood, mucus or other bodily fluids can harbor pathogens like *Clostridium difficile* for extended periods.
- Food Residue: Surfaces in kitchens and food preparation areas are often contaminated with food residues that provide an ideal environment for bacteria such as *Salmonella*, *Listeria monocytogenes* and *Escherichia coli*. This is particularly true in environments with improper cleaning practices, where leftover food particles allow bacteria to thrive.

3.4. Pathogen Characteristics

Different microorganisms exhibit varying abilities to survive on fomites based on their inherent characteristics, such as cell structure and resistance to environmental stressors.

- Viruses: Enveloped viruses, like SARS-CoV-2 and influenza, tend to be more sensitive to environmental conditions compared to non-enveloped viruses such as norovirus and adenovirus. Non-enveloped viruses have a more stable capsid structure, allowing them to survive for longer periods on fomites in adverse conditions such as low humidity and high temperatures. For example, norovirus, which causes gastroenteritis, can survive on surfaces for weeks, making it a key pathogen of concern for fomite transmission.
- Bacteria: Bacteria with spore-forming capabilities, such as *Clostridium difficile*, can survive on fomites for long periods under extreme conditions, including heat, desiccation and chemical disinfection. Spores are highly resistant to environmental stressors, which explain why *C. difficile* can persist on hospital surfaces for months despite routine cleaning and disinfection.

3.5. Exposure to Disinfectants and Cleaning Agents

The use of disinfectants and cleaning protocols significantly affects microbial survival on fomites. Proper disinfection can reduce or eliminate pathogens from surfaces, but the efficacy of disinfection depends on the type of cleaning agents used and how thoroughly surfaces are cleaned.

- Efficacy of Disinfectants: Many commonly used disinfectants, such as bleach (sodium hypochlorite) and alcohol-based solutions (ethanol and isopropanol), are effective in killing bacteria and viruses on surfaces. However, microorganisms like *Clostridium difficile* spores and certain fungi may be resistant to standard disinfection practices. Ineffective or infrequent disinfection can lead to the persistence of pathogens on fomites, contributing to outbreaks, particularly in healthcare settings.
- Biofilm Formation: Some bacteria, such as *Pseudomonas aeruginosa* and *Staphylococcus epidermidis*, can form biofilms—a protective layer that shields the microbial community from disinfectants and environmental stressors. Biofilms enhance microbial survival on fomites and make cleaning more difficult. Biofilm-forming microorganisms are common in healthcare environments and are associated with infections related to medical devices and equipment.

3.6. Frequency of Surface Contact

Surfaces that are frequently touched, known as "high-touch surfaces," such as doorknobs, elevator buttons and handrails, are more likely to accumulate microorganisms. High-touch fomites serve as reservoirs for the transmission of pathogens in public spaces, schools, offices and hospitals. The higher the frequency of contact, the greater is the potential for microbial contamination and transmission. Regular cleaning and disinfection of these surfaces are necessary to reduce the risk of microbial survival.

4. Mechanisms of Transmission via Fomites

Fomite-mediated transmission occurs when microorganisms present on contaminated surfaces are transferred to individuals, leading to infection. This mode of transmission is particularly significant for respiratory, gastrointestinal and skin-related pathogens. The mechanisms of transmission via fomites involve several key processes: contamination, persistence of pathogens on surfaces, transfer to hosts and subsequent infection [11-13]. Understanding these mechanisms is essential for controlling the spread of infectious diseases in healthcare settings, public spaces and households.

4.1. Contamination of Fomites

Fomites become contaminated when they come into contact with infected individuals, bodily fluids or contaminated objects. Pathogens are transferred to surfaces through direct contact with human skin, respiratory droplets or bodily secretions or indirectly via contaminated hands or objects.

- Respiratory Droplets: Many respiratory pathogens, such as SARS-CoV-2, influenza virus and rhinovirus, are transmitted via respiratory droplets that are expelled when an infected individual coughs, sneezes or talks. These droplets can settle on surfaces, contaminating fomites in both healthcare and community settings. During the COVID-19 pandemic, respiratory droplets were recognized as a major source of surface contamination in public spaces and hospitals, necessitating frequent cleaning and disinfection protocols.
- Direct Contact: Infected individuals can transfer pathogens to fomites through direct contact. Skin-associated pathogens, such as *Staphylococcus aureus* and *Streptococcus pyogenes*, can be transferred to high-touch surfaces like doorknobs, handrails and medical instruments through skin-to-surface contact. Healthcare workers, for instance, can transfer microorganisms from patient skin to surfaces if proper hand hygiene is not followed.
- Bodily Fluids: Pathogens present in bodily fluids, such as saliva, blood, feces or urine, can contaminate fomites if these fluids come into contact with surfaces. For example, gastrointestinal viruses like norovirus can spread when contaminated hands, vomit or feces come into contact with surfaces in bathrooms or food preparation areas. Bloodborne pathogens, including hepatitis B and HIV, can also contaminate medical equipment or surfaces during procedures involving blood.

4.2. Persistence of Microorganisms on Fomites

Once pathogens have contaminated a surface, their ability to survive on the fomite for extended periods influences the likelihood of transmission. The persistence of microorganisms on fomites depends on factors such as the type of pathogen, the nature of the surface and environmental conditions (e.g., humidity, temperature).

- Bacteria: Bacterial pathogens, such as *Staphylococcus aureus* and *Escherichia coli*, can survive on fomites for hours to days. Studies have shown that MRSA can remain viable on surfaces like plastic and stainless steel for extended periods, making these surfaces significant vectors for bacterial transmission in hospitals and communal environments. The ability of bacteria to form biofilms—a matrix that protects microbial communities—further enhances their persistence on surfaces, particularly in moist environments.
- Viruses: Viruses also vary in their ability to persist on fomites. Non-enveloped viruses like norovirus can remain infectious on surfaces for days to weeks, while enveloped viruses such as SARS-CoV-2 are more sensitive to environmental conditions but can still persist on plastic or metal surfaces for up to 72 hours. Norovirus is highly stable in the environment, making it a significant cause of outbreaks in settings like cruise ships, hospitals and schools.

4.3. Transfer of Microorganisms to Hosts

The transfer of microorganisms from fomites to a new host typically occurs through indirect contact, where individuals touch a contaminated surface and then touch their mouth, nose, eyes or an open wound. This process of "self-inoculation" is a key mechanism for the transmission of pathogens via fomites.

- Hand-to-Face Contact: Hands serve as the primary medium for transferring pathogens from fomites to mucous membranes (e.g., mouth, nose, eyes), leading to infection. Studies show that individuals touch their faces frequently, increasing the risk of self-inoculation with pathogens picked up from contaminated surfaces. This is a common route of transmission for respiratory infections like the common cold and influenza, as well as gastrointestinal pathogens like norovirus and *Salmonella*.
- Hand-to-Food Contact: In food preparation environments, hands that come into contact with contaminated fomites can transfer pathogens to food items, leading to foodborne illness. Pathogens like *Escherichia coli*,

Salmonella and *Listeria monocytogenes* are commonly associated with cross-contamination from contaminated surfaces in kitchens, restaurants and food processing facilities.

- Contact with Mucous Membranes or Open Wounds: In healthcare settings, contaminated surfaces can lead to the transmission of pathogens via contact with mucous membranes, surgical sites or open wounds. For example, *Clostridium difficile* spores can be transferred from contaminated surfaces to patients through healthcare workers' hands or medical equipment, causing severe gastrointestinal infections.

4.4. Infection in the Host

Once transferred to a susceptible host, the microorganism must overcome the host's immune defenses to establish an infection. The success of transmission depends on the pathogen's infectious dose (the minimum number of organisms required to cause infection) and the host's immune status.

- Infectious Dose: The amount of pathogen transferred from the fomite to the host influences the likelihood of infection. Some pathogens, like norovirus, have a low infectious dose, meaning that only a few viral particles are needed to cause illness. In contrast, other pathogens require higher doses to establish an infection. The amount of microbial contamination on a surface and the frequency of contact with that surface affect the dose that can be transferred to a host.
- Host Susceptibility: Individuals with compromised immune systems, such as the elderly, young children and patients in hospitals, are more susceptible to infections from pathogens transmitted via fomites. For instance, immune compromised patients are at a higher risk of acquiring healthcare-associated infections (HAIs) from contaminated surfaces in medical environments.

4.5. Prevention of Fomite Transmission

Preventing fomite-mediated transmission requires a combination of strategies, including regular cleaning and disinfection of high-touch surfaces, promoting hand hygiene and minimizing contact with contaminated surfaces. Key prevention measures include:

- Disinfection: The use of effective disinfectants on high-touch surfaces, such as doorknobs, handrails and medical equipment, is critical in reducing the risk of fomite transmission. Studies show that disinfectants containing bleach, alcohol or hydrogen peroxide are effective against a broad range of microorganisms, including bacteria, viruses and fungi .
- Hand Hygiene: Proper handwashing with soap and water or the use of alcohol-based hand sanitizers is one of the most effective ways to prevent the transfer of pathogens from fomites to the host. Regular hand hygiene is especially important in healthcare settings and public spaces, where contact with contaminated surfaces is frequent .
- Surface Hygiene: Cleaning protocols in hospitals, schools and public spaces should focus on frequently touched surfaces, such as phones, desks and light switches. In food preparation areas, strict hygiene standards help prevents cross-contamination between surfaces and food.

5. Diseases Commonly Spread via Fomites

Fomites or contaminated inanimate objects and surfaces, play a significant role in the transmission of a variety of infectious diseases. The pathogens responsible for these diseases can be transmitted via indirect contact when a person touches a contaminated surface and then their face, mucous membranes or wounds [14,15]. Below are some of the most common diseases spread via fomites, spanning respiratory, gastrointestinal, skin and other infectious diseases.

5.1. Respiratory Infections

Respiratory viruses are among the most frequently transmitted pathogens via fomites. These viruses often persist on surfaces for extended periods and can infect individuals through indirect contact with mucous membranes in the nose, eyes or mouth.

- COVID-19 (SARS-CoV-2): The novel coronavirus responsible for COVID-19 spreads primarily through respiratory droplets, but fomites also contribute to its transmission. Research has demonstrated that SARS-CoV-2 can survive on surfaces like plastic and stainless steel for up to 72 hours, making high-touch surfaces like doorknobs, elevator buttons and phones significant vectors of transmission in public and healthcare settings. The virus can be transferred from contaminated surfaces to hands and subsequently to mucous membranes.

- Influenza: Influenza viruses are also known to survive on surfaces for several hours to days, depending on environmental conditions. Fomite transmission of influenza occurs when contaminated hands touch the nose, mouth or eyes after coming into contact with a contaminated surface. Studies have shown that influenza A can persist on stainless steel and plastic surfaces for 24 to 48 hours, especially in environments like schools, workplaces and public transportation, where high-touch surfaces are prevalent.
- Rhinovirus (Common Cold): Rhinoviruses, the most common cause of the common cold, are readily transmitted via fomites. These viruses can survive on surfaces for hours to days, depending on environmental factors like humidity and temperature. Fomite transmission plays a significant role in the spread of rhinoviruses in households, schools and workplaces. Research has found that rhinoviruses can survive for several hours on surfaces such as door handles and telephones, leading to frequent outbreaks in crowded environments.

5.2. Gastrointestinal Infections

Many gastrointestinal pathogens are transmitted through contaminated surfaces, particularly in environments with poor hygiene and sanitation. These infections are often spread via the fecal-oral route, where pathogens are transferred from surfaces to hands and then ingested.

- Norovirus: Norovirus is one of the most common causes of viral gastroenteritis and is highly stable in the environment. It can survive on surfaces for weeks, making fomite transmission a key route of spread in places like hospitals, cruise ships, schools and food service environments. Contaminated hands, food or surfaces can easily transmit the virus, which has a very low infectious dose. Outbreaks of norovirus often occur in settings where shared surfaces, such as bathroom fixtures, countertops and dining tables, are not adequately disinfected.
- Rotavirus: Rotavirus, a major cause of severe diarrhea in young children, is also transmitted via fomites. The virus can survive on hard surfaces for several days and is spread through contact with contaminated objects or hands. In daycare centers, schools and hospitals, fomites such as toys, diapers and changing tables serve as reservoirs for rotavirus, especially when hygiene practices are inadequate.
- *Salmonella* and *Escherichia coli (E. coli*): These bacteria are common causes of foodborne illness and can be transmitted via fomites when contaminated surfaces come into contact with food. In kitchen environments, cutting boards, utensils and countertops are frequent sources of contamination with *Salmonella* and *E. coli*, leading to outbreaks of gastrointestinal disease. Fomite transmission is a particular concern in food processing facilities and homes where proper sanitation and cleaning are not followed.

5.3. Skin Infections

Pathogens responsible for skin infections can easily spread through fomites, particularly in environments where personal items like towels, linens and clothing are shared or frequently handled.

Methicillin-resistant ***Staphylococcus aureus*** (MRSA): MRSA is a highly resistant strain of *Staphylococcus aureus* and is a significant cause of healthcare-associated infections. It can survive on surfaces like linens, towels and medical equipment for days to weeks, making fomite transmission a concern in hospitals, nursing homes and gyms. MRSA can be transferred from contaminated surfaces to the skin, leading to infections like boils, abscesses and cellulitis. Fomite transmission is especially problematic in hospitals, where equipment like bed rails, doorknobs and surgical instruments can become contaminated if not properly disinfected.

Fungal Infections (Dermatophytes): Fungi, such as *Trichophyton* species, which cause athlete's foot, ringworm and other dermatophytoses, are commonly spread via contaminated surfaces in communal areas. Locker rooms, gyms, swimming pools and shared shower areas are prime environments for fomite transmission of fungal infections. Towels, floors and gym equipment can become contaminated with fungal spores, which are then transmitted to individuals' skin.

5.4. Other Infectious Diseases

In addition to respiratory, gastrointestinal and skin infections, several other infectious diseases can be spread through fomites.

- Clostridium difficile (C. diff): *C. difficile* is a spore-forming bacterium that causes severe diarrhea and colitis, primarily in hospitalized patients or those on long-term antibiotics. *C. difficile* spores can survive on surfaces for extended periods and are resistant to many common disinfectants. Fomite transmission in healthcare settings occurs when contaminated hands or surfaces come into contact with vulnerable patients. Bed rails, medical devices and bathroom fixtures are common fomites for *C. difficile* transmission in hospitals.

- Hepatitis A: Hepatitis A, a viral infection that affects the liver, is transmitted via the fecal-oral route and can spread through fomites in environments with poor hygiene. Surfaces contaminated with fecal matter, such as bathroom fixtures and food preparation areas, can harbor the virus. In settings where hand hygiene is inadequate, fomite transmission of hepatitis A is a concern, especially in outbreaks associated with foodborne transmission.
- Respiratory Syncytial Virus (RSV): RSV is a common cause of respiratory infections in young children and the elderly. It can survive on surfaces like toys, tables and bedding for hours, making fomite transmission a significant concern in daycare centers and hospitals. RSV is easily spread through direct contact with contaminated surfaces, leading to outbreaks in environments where individuals are in close proximity.

6. Factors Influencing Fomite-Based Disease Spread

The spread of infectious diseases through fomites depends on a complex interplay of factors related to the microorganisms, the contaminated surfaces, the environment and human behavior. These factors influence how long microorganisms can survive on surfaces, how effectively they are transferred to new hosts and the likelihood of causing infection. Understanding these factors is crucial for developing strategies to mitigate fomite-based disease transmission, particularly in healthcare settings, schools and public spaces [16,17].

6.1. Type of Microorganism

Different pathogens exhibit varying capacities for survival on surfaces and transmission via fomites. The characteristics of the microorganism, such as its structure, resilience and infectious dose, play a significant role in fomite-based disease spread.

- Bacteria: Gram-positive bacteria, such as *Staphylococcus aureus* (including MRSA), generally survive longer on surfaces than Gram-negative bacteria like *Escherichia coli*, due to the thicker peptidoglycan layer in their cell walls, which offers better protection against environmental stresses . Spore-forming bacteria, such as *Clostridium difficile*, are particularly resistant and can persist on surfaces for weeks or months in a dormant state, leading to prolonged risks of fomite-based transmission.
- Viruses: Enveloped viruses, such as influenza and coronaviruses (e.g., SARS-CoV-2), are more susceptible to environmental degradation compared to non-enveloped viruses like norovirus. However, SARS-CoV-2 has been shown to survive on surfaces for up to 72 hours under ideal conditions, contributing to fomite-based transmission in public spaces. In contrast, non-enveloped viruses, which lack a lipid envelope, tend to be more stable on surfaces and resistant to disinfectants, making them more likely to spread through fomites.
- Fungi: Fungal pathogens, especially dermatophytes like *Trichophyton* spp. (responsible for athlete's foot and ringworm), can survive on surfaces like gym floors, towels and communal showers, facilitating their spread in public spaces. Fungal spores are highly resilient, enabling long-term survival on fomites.

6.2. Surface Type

The material and texture of a surface significantly affect the survival of microorganisms and the likelihood of fomite-based transmission. Different surfaces provide varying levels of protection or exposure to microorganisms.

- Hard, Non-Porous Surfaces: Smooth surfaces like stainless steel, plastic and glass tend to harbor microorganisms for longer periods compared to porous surfaces. Research has shown that viruses such as SARS-CoV-2 and influenza A can survive for days on hard, non-porous surfaces like doorknobs, elevator buttons and countertops, making them major vectors for disease transmission in public spaces and healthcare settings.
- Porous Surfaces: In contrast, porous materials like fabric, paper and wood tend to absorb moisture, which can reduce the survival time of many microorganisms. However, some pathogens, such as certain fungi and *Clostridium difficile* spores, can still persist on porous surfaces, especially if moisture levels are high. Porous surfaces also offer less opportunity for transfer to human hands or other objects due to reduced contact area.
- Biofilm Formation: On both porous and non-porous surfaces, some bacteria form biofilms—a protective layer of extracellular polymeric substances that enhance bacterial survival and resistance to cleaning. Biofilms can develop on medical devices, water systems and even household surfaces, significantly increasing the risk of fomite-based transmission, especially for pathogens like *Pseudomonas aeruginosa* and *Staphylococcus aureus*.

6.3. Environmental Conditions

The surrounding environment greatly impacts the survival of microorganisms on fomites. Factors such as temperature, humidity and sunlight exposure all play crucial roles in determining how long pathogens remain viable on surfaces.

- Temperature: Higher temperatures generally reduce the survival time of most microorganisms on surfaces. However, some pathogens are more resistant to temperature changes. For example, norovirus can remain infectious at room temperature for several weeks, while bacteria like *Staphylococcus aureus* tend to survive better in cooler conditions.
- Humidity: The survival of viruses and bacteria on fomites is often influenced by humidity levels. In dry environments, many microorganisms, especially enveloped viruses, tend to lose viability more quickly. For instance, influenza viruses have been shown to survive longer on surfaces in humid conditions, while they become inactivated more quickly in dry air. Conversely, bacteria like *Escherichia coli* and *Staphylococcus aureus* may persist longer on surfaces under high-humidity conditions due to the availability of moisture.
- Ultraviolet Light (UV): Exposure to sunlight or artificial UV light can inactivate many microorganisms on surfaces. UV radiation damages microbial DNA and RNA, reducing their infectivity. Therefore, surfaces exposed to sunlight or UV light are less likely to harbor viable pathogens for extended periods. UV disinfection is commonly used in healthcare settings to reduce fomite contamination.

6.4. Human Behavior

Human contact with fomites and subsequent actions, such as touching the face or other objects, significantly impact the likelihood of disease transmission. Human behavior plays a central role in facilitating or preventing the spread of pathogens via fomites.

- Frequency of Contact: Frequently touched surfaces or "high-touch" surfaces, such as doorknobs, handrails, light switches and mobile phones, are more likely to become contaminated and serve as vectors for disease transmission. The more often a surface is touched, the higher the chances of microbial transfer between hands and the surface, increasing the risk of spreading infections like influenza, rhinovirus and SARS-CoV-2.
- Hand Hygiene: Poor hand hygiene is a major factor in fomite-based transmission. Studies shows that people touch their faces frequently, making it easy for pathogens on contaminated surfaces to reach mucous membranes and enter the body. Proper hand hygiene, including washing hands with soap and water or using alcohol-based hand sanitizers, is one of the most effective measures for preventing the transfer of pathogens from fomites to individuals. Inadequate hand hygiene, particularly in healthcare settings, can result in the spread of healthcare-associated infections (HAIs) .
- Cleaning and Disinfection Practices: Regular cleaning and disinfection of high-touch surfaces can significantly reduce the risk of fomite-based transmission. However, the effectiveness of cleaning practices depends on the type of disinfectant used and the frequency of cleaning. Surfaces in hospitals, public transportation and workplaces must be disinfected frequently to minimize contamination. Disinfectants containing alcohol, bleach or hydrogen peroxide are generally effective against a broad range of pathogens, including enveloped viruses like SARS-CoV-2 and bacteria like *Staphylococcus aureus*.

6.5. Host Factors

The susceptibility of individuals to infection also influences fomite-based disease spread. The risk of transmission and severity of infection depend on factors related to the host, such as immune status, age and pre-existing conditions.

- Immune Status: Immuno compromised individuals, such as patients undergoing chemotherapy, transplant recipients and individuals with HIV, are more susceptible to infections from pathogens transmitted via fomites. In healthcare settings, where immune compromised patients are more common, the importance of preventing fomite-based transmission is even greater.
- Age and Vulnerability: Infants, young children and the elderly are particularly vulnerable to infections spread via fomites, as their immune systems may not be as robust. In schools, daycare centers and long-term care facilities, frequent outbreaks of gastrointestinal and respiratory diseases, such as rotavirus, norovirus and influenza, are often linked to fomite transmission due to the high-touch environment and vulnerable populations.
- Infectious Dose: The infectious dose or the number of microorganisms required to cause infection, varies between pathogens. For example, norovirus has a very low infectious dose, meaning that even small amounts of the virus on surfaces can lead to illness. In contrast, some bacteria and viruses require a higher number of organisms to cause infection, making surface contamination with low pathogen loads less likely to lead to disease.

7. Strategies for Preventing Fomite-Mediated Transmission

Fomite-mediated transmission of infectious diseases can be effectively mitigated by implementing a range of preventative strategies. These strategies are focused on reducing the contamination of surfaces, limiting the survival of pathogens on fomites and minimizing the transfer of pathogens from surfaces to humans [3]. These interventions are particularly crucial in settings like hospitals, schools, public transport and households where there is frequent contact with shared surfaces. Below are the key strategies for preventing fomite-mediated transmission [18,19].

7.1. Effective Cleaning and Disinfection

Regular cleaning and disinfection of frequently touched surfaces play a critical role in reducing microbial contamination on fomites. The type of disinfectant, cleaning frequency and methods used significantly impact the effectiveness of this strategy.

- High-Touch Surfaces: Areas such as doorknobs, handrails, light switches, elevator buttons and bathroom fixtures are frequently touched by multiple people and should be prioritized for cleaning and disinfection. Disinfectants containing alcohol (60–90%), hydrogen peroxide or chlorine compounds are highly effective against a broad spectrum of pathogens, including SARS-CoV-2, influenza and *Staphylococcus aureus*.
- Healthcare Settings: In healthcare environments, specialized cleaning protocols are essential to prevent the transmission of healthcare-associated infections (HAIs). Terminal cleaning of patient rooms, the use of ultraviolet (UV) light or hydrogen peroxide vapor systems and routine disinfection of medical equipment are important strategies to prevent fomite-mediated spread of pathogens such as *Clostridium difficile* and MRSA.
- Household and Public Spaces: In households and public spaces, regular cleaning of shared objects (e.g., mobile phones, tablets and remote controls) and surfaces such as countertops and kitchen areas is necessary to reduce contamination. Studies show that proper disinfection of frequently touched surfaces can significantly reduce the microbial load and, consequently, the risk of disease transmission.

7.2. Hand Hygiene

Proper hand hygiene is one of the most effective measures to prevent the transfer of pathogens from fomites to individuals. This simple yet crucial practice can interrupt the transmission cycle of many diseases, especially in environments where surface contamination is common.

- Handwashing with Soap and Water: The Centers for Disease Control and Prevention (CDC) recommends washing hands with soap and water for at least 20 seconds, especially after touching high-touch surfaces, using the restroom and before eating. Soap breaks down the lipid membranes of many viruses, such as coronaviruses and influenza, making them easier to remove from the skin.
- Alcohol-Based Hand Sanitizers: In the absence of soap and water, alcohol-based hand sanitizers (with at least 60% alcohol content) are effective in inactivating a wide range of pathogens, including enveloped viruses like SARS-CoV-2 and many bacteria. However, alcohol-based sanitizers may be less effective against certain non-enveloped viruses and bacterial spores, such as norovirus and *Clostridium difficile*.
- Healthcare and Public Settings: In healthcare and public settings, promoting hand hygiene through the availability of hand sanitizing stations and visible reminders (e.g., posters) can encourage adherence. Healthcare workers should follow strict hand hygiene protocols before and after patient contact, as well as before handling medical equipment to prevent fomite-mediated transmission.

7.3. Minimizing Contact with Contaminated Surfaces

Reducing contact with contaminated surfaces is another strategy to mitigate the spread of infectious diseases via fomites. This can be achieved through behavioral modifications and environmental interventions.

- Touchless Technology: The adoption of touchless technology, such as automatic doors, touch-free faucets and motion-sensor trash cans, can reduce the need for individuals to touch contaminated surfaces. In public restrooms and hospitals, touchless soap dispensers, paper towel dispensers and hand dryers can also help minimize contact with potentially contaminated surfaces.
- Use of Barriers: Barriers like disposable gloves or tissues can prevent direct contact with high-touch surfaces, especially in public spaces. For example, people can use tissues to handle door handles or press elevator buttons, reducing the likelihood of contaminating their hands with pathogens present on these surfaces.
- Public Awareness Campaigns: Educating the public about avoiding unnecessary contact with frequently touched surfaces and the importance of using personal protective equipment (PPE) can significantly reduce the

risk of fomite-mediated disease transmission. Campaigns promoting the use of gloves in grocery stores or encouraging the use of elbows instead of hands to open doors have been shown to reduce fomite contamination during disease outbreaks.

7.4. Use of Antimicrobial Materials

Incorporating antimicrobial materials into surfaces and objects can reduce the survival of pathogens and prevent fomite-based transmission. These materials, which include metals like copper and silver, are particularly effective in healthcare environments where frequent contamination occurs.

- Copper-Alloy Surfaces: Research has shown that copper and its alloys (such as brass and bronze) have strong antimicrobial properties, killing a wide range of pathogens, including bacteria (e.g., MRSA, *E. coli*) and viruses (e.g., influenza, SARS-CoV-2). Copper surfaces have been shown to reduce the microbial load in hospital settings, where contamination of bed rails, doorknobs and medical equipment is common.
- Silver-Impregnated Surfaces: Silver nanoparticles have antimicrobial properties and are being incorporated into a variety of materials, including wound dressings, textiles and coatings for medical devices. These materials inhibit microbial growth and reduce the risk of fomite-based transmission, particularly in healthcare settings where sterility is critical.
- Long-Lasting Antimicrobial Coatings: Some new technologies involve the application of long-lasting antimicrobial coatings that provide continuous protection on frequently touched surfaces. These coatings can kill or inhibit microorganisms for extended periods, reducing the need for frequent cleaning and disinfection in high-traffic areas.

7.5. Environmental Controls

Certain environmental modifications and controls can reduce the risk of fomite-mediated disease transmission by altering the environmental factors that promote microbial survival on surfaces.

- Temperature and Humidity Control: Maintaining environmental conditions that are less conducive to microbial survival can reduce the risk of transmission. For example, controlling indoor humidity levels and temperature can help limit the survival of respiratory viruses like influenza and SARS-CoV-2, which tend to survive longer in cool, humid environments.
- UV Light Disinfection: Ultraviolet-C (UVC) light is highly effective in deactivating a wide range of pathogens on surfaces by damaging their nucleic acids. UVC disinfection systems are increasingly being used in hospitals to sterilize patient rooms, operating theaters and medical equipment, thereby reducing fomite-based transmission. UVC robots are also being employed in some healthcare settings to provide automated, whole-room disinfection.
- Ventilation: Proper ventilation in indoor spaces reduces the accumulation of airborne particles that may settle on surfaces and lead to contamination. Improved air exchange rates and the use of high-efficiency particulate air (HEPA) filters can decrease the overall microbial load in enclosed environments, which, in turn, reduces surface contamination.

7.6. Personal Protective Equipment (PPE)

In certain high-risk environments, such as healthcare settings or during outbreaks, the use of personal protective equipment (PPE) is necessary to prevent fomite-based transmission.

- Gloves: Wearing gloves can protect individuals from direct contact with contaminated surfaces, particularly in healthcare or laboratory settings where the risk of surface contamination with pathogens like *Clostridium difficile* or MRSA is high. However, gloves must be changed regularly and disposed of properly to avoid cross-contamination.
- Gowns and Aprons: In healthcare settings, protective clothing like gowns and aprons prevent healthcare workers from contaminating their clothing with pathogens from surfaces. These garments serve as a barrier, protecting the wearer from direct exposure to infectious agents on fomites.

8. Conclusion

Fomite-mediated transmission of infectious diseases poses a significant public health challenge, particularly in environments where high-touch surfaces are common, such as healthcare settings, schools and public transportation. Understanding the dynamics of microbial survival on fomites, the types of pathogens involved and the factors

influencing transmission is crucial for developing effective prevention strategies. This comprehensive approach encompasses rigorous cleaning and disinfection protocols, the promotion of hand hygiene, the use of touchless technologies and the incorporation of antimicrobial materials into frequently touched surfaces.

Effective cleaning and disinfection, combined with regular hand hygiene practices, can significantly reduce the microbial load on fomites and interrupt the transmission cycle of infectious diseases. Moreover, minimizing direct contact with contaminated surfaces through behavioral modifications and environmental controls, such as UV disinfection and optimal ventilation, is essential for reducing risk. The use of personal protective equipment (PPE) in high-risk settings further enhances safety by providing additional barriers against contamination.

Education and awareness campaigns play a vital role in fostering a culture of hygiene, urging individuals to adopt preventive measures actively. As pathogens continuously evolve, it is imperative for public health officials and institutions to stay vigilant and adapt their strategies to effectively manage the risk of fomite-mediated transmission.

Ultimately, a multi-faceted approach that combines hygiene practices, environmental controls and public awareness can significantly curb the spread of infectious diseases via fomites. By implementing these strategies consistently and rigorously, we can protect vulnerable populations and contribute to a healthier society. Ongoing research into novel disinfection technologies and antimicrobial materials will further strengthen our capacity to combat the challenges posed by fomite-mediated transmission in the future.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Boone, S. A., & Gerba, C. P. (2007). Significance of fomites in the spread of respiratory and enteric viral disease. *Applied and Environmental Microbiology, 73*(6), 1687-1696.

[2] Boyce, J. M., & Pittet, D. (2002). Guideline for hand hygiene in health-care settings: recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. *Infection Control and Hospital Epidemiology, 23*(12), S3-S40.

[3] Casey, A. L., Adams, D., Karpanen, T. J., Lambert, P. A., Cookson, B. D., Nightingale, P., ... & Elliott, T. S. J. (2010). Role of copper in reducing hospital environment contamination. *Journal of Hospital Infection, 74*(1), 72-77.

[4] Ciorba, V., Odone, A., Veronesi, L., Pasquarella, C., & Signorelli, C. (2012). Cleaning and disinfection of high-touch surfaces in hospitals: a unit-based protocol. *Journal of Preventive Medicine and Hygiene, 53*(4), 191-194.

[5] Flemming, H. C., & Wingender, J. (2010). The biofilm matrix. *Nature Reviews Microbiology, 8*(9), 623-633.

[6] Gerba, C. P., & Choi, C. Y. (2006). The role of fomites in cross-contamination during food preparation. *Food Protection Trends, 26*(11), 896-900.

[7] Gerhardts, A., Hammer, T. R., Balluff, C., Mucha, H., & Hoefer, D. (2012). A model of the transmission of micro-organisms in a public setting and its correlation to pathogen infection risks. *Journal of Applied Microbiology, 112*(2), 614-621.

[8] Kampf, G. (2018). Efficacy of ethanol against viruses in hand disinfection. *The Journal of Hospital Infection, 98*(4), 331-338.

[9] Kampf, G., & Kramer, A. (2004). Epidemiologic background of persistent nosocomial pathogens. *BMC Infectious Diseases, 4*(1), 1-8.

[10] Kampf, G., & Kramer, A. (2014). Epidemiologic background of persistent nosocomial pathogens. *Journal of Hospital Infection, 86*(1), 19-27.

[11] Kampf, G., & Kramer, A. (2018). Efficacy of ethanol against viruses in hand disinfection. *The Journal of Hospital Infection, 98*(4), 331-338.

[12] Kampf, G., Todt, D., Pfaender, S., & Steinmann, E. (2020). Persistence of coronaviruses on inanimate surfaces and their inactivation with biocidal agents. *Journal of Hospital Infection, 104*(3), 246-251.

[13] Kramer, A., Schwebke, I., & Kampf, G. (2006). How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infectious Diseases, 6*(130), 1-8.

[14] Otter, J. A., Yezli, S., & French, G. L. (2011). The role played by contaminated surfaces in the transmission of nosocomial pathogens. *Infection Control and Hospital Epidemiology, 32*(7), 687-699.

[15] Otter, J. A., Yezli, S., Salkeld, J. A. G., & French, G. L. (2013). Evidence that contaminated surfaces contribute to the transmission of hospital pathogens and an overview of strategies to address contaminated surfaces in hospital settings. *American Journal of Infection Control, 41*(5), S6-S11.

[16] Rutala, W. A., & Weber, D. J. (2019). Best practices for disinfection of noncritical surfaces in healthcare facilities: a bundle approach. *American Journal

[17] Sattar, S. A., & Maillard, J. Y. (2013). The crucial role of wiping in decontamination of high-touch environmental surfaces: review of current status and directions for the future. *American Journal of Infection Control, 41*(5), S97-S104.

[18] Van Doremalen, N., Bushmaker, T., Morris, D. H., Holbrook, M. G., Gamble, A., Williamson, B. N., & Munster, V. J. (2020). Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *The New England Journal of Medicine, 382*(16), 1564-1567.

[19] Weber, D. J., Anderson, D., & Rutala, W. A. (2013). The role of the environment in transmission of Clostridium difficile infection in healthcare facilities. *Infection Control & Hospital Epidemiology, 34*(4), 507-513.