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RAISING AWARENESS OF TEXTILE WASTE CONTAMINATION DANGER

BY

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Abstract. Textiles are fundamental materials in fashion industries and other sectors, including healthcare and food service. Textiles can easily be contaminated with viruses, bacteria, and other harmful microorganisms that can cause many diseases. Reducing the risk of transmission of micro-organisms, especially in a tragic post-pandemic context, has become one of the greatest modern concerns. Diverse methods of textile decontamination can be discussed, including thermal, chemical, and physical techniques and their effectiveness in eliminating microorganisms. In recent years, textile and footwear recycling has become a priority for the fashion industry due to its negative impact on the environment. Before being recycled, textile waste should be decontaminated to avoid the spread of pathogen agents. The purpose of this state-of-the-art research is to raise awareness regarding the need of establishing a decontamination step at the beginning of the textile waste recycling process to maintain safety standards from both the facility cross-contamination viewpoint and the human resource perspective.

Keywords: textile life cycle, pathogens in textiles, disinfectant substances, biological load, recycling steps.

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1. Introduction

Pathogen agents found in textile waste can originate from various sources, including human shedding, animal waste, and environmental contamination. Among the pathogens commonly detected are bacteria, viruses, and fungi, including species such as Staphylococcus aureus, Escherichia coli, Candida albicans, and Pseudomonas aeruginosa. These microorganisms can survive on textiles for extended periods, with some studies reporting their persistence for weeks or even months (Poddar and Chandrasekaran, 2019; Mendelson *et al*., 2020). The endurance and transference mechanisms of pathogens in textile waste are determined by many factors, including the type of pathogen the presence of organic matter, and environmental conditions. A few bacteria, such as Escherichia coli and Staphylococcus aureus, can form biofilms on textile surfaces, providing protection and enhancing their survival (Poddar and Chandrasekaran, 2019). Viruses, including noroviruses, can persist viable on textiles and contribute to the transference of infections through direct contact or aerosolization (Mendelson *et al*., 2020). Textile waste has become a significant environmental concern due to its increasing volume and potential impacts on public health. The presence of pathogen agents in textile waste poses potential risks to public health. When contaminated textiles come into contact with the skin, there is a possibility of direct transmission of pathogens, leading to skin infections, respiratory illnesses, or gastrointestinal disturbances. Moreover, if textile waste is not adequately managed, there is a potential for the release of pathogens into the environment, contributing to the spread of infectious diseases. This state-of-the-art review explores the presence and characteristics of pathogen agents found in textile waste, shedding light on the potential risks associated with their exposure (Johnson *et al*., 2020). The review synthesizes current literature to provide an overview of the major types of pathogens identified, their survival and transmission mechanisms, and the implications for public health (Rodriguez *et al*., 2018). Furthermore, it discusses potential mitigation strategies and identifies research gaps to guide future investigations in this emerging field.

2. Pathogen Agents in Textile Waste

Bacterial pathogens commonly detected in textile waste include Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa. These microorganisms can remain for long periods, thereby growing the potential for infection and transmission (Poddar and Chandrasekaran, 2019).

Staphylococcus aureus is a gram-positive bacterium that may cause skin and soft tissue infections, as well as more serious conditions like pneumonia and bloodstream infections, from minor skin and soft tissue infections to serious invasive diseases. *Staphylococcus aureus* causes a wide variety of virulence vectors that contribute to its pathogenicity. Among these are surface proteins, enzymes, toxins, and the ability to form biofilms. The bacteria's capacity to escape the immune system and develop tolerance to antibiotics further complicates the management of infections caused by this agent. Infections of the skin and soft tissues associated with *Staphylococcus aureus* include cellulitis, impetigo, abscesses, and cutaneous infections. In rare cases, these infections can lead to more serious conditions such as necrotizing fasciitis or bacteraemia. *Staphylococcus aureus* is also a leading cause of healthcare-associated infections, including surgical site infections, pneumonia, and bloodstream infections. Moreover, certain strains of Staphylococcus aureus are known to produce toxins such as enterotoxins and toxic shock syndrome toxin-1, which can cause food poisoning and toxic shock syndrome (Poddar and Chandrasekaran, 2019).

Escherichia coli, a gram-negative bacterium, includes some strains that can provoke gastrointestinal disease, urinary tract infections, and, in rarely encountered cases, major medical complications like haemolytic uraemic syndrome. A well-recognized pathogenic strain of *E. coli* is *Escherichia coli O157:H7,* that causes a powerful toxin called Shiga toxin. *E. coli* exists naturally in the digestive tracts of animals and humans. Whereas most varieties of *E. coli* are completely harmless and occasionally even beneficial, some strains of pathogenic E. coli can cause a wide variety of diseases. This strain is associated with foodborne outbreaks and can cause severe gastrointestinal illnesses, including bloody diarrhoea and, in some cases, haemolytic uremic syndrome (HUS), a condition characterized by kidney failure and low platelet count. Other pathogenic strains of *E. coli*, collectively known as diarrheagenic *E. coli*, can also cause gastrointestinal infections. These include enterotoxigenic *E. coli* (ETEC), enteropathogenic *E. coli* (EPEC), entero-invasive *E. coli* (EIEC), enterohemorrhagic *E. coli* (EHEC), and enteroaggregative *E. coli* (EAEC). Each strain possesses distinct virulence factors and mechanisms of pathogenesis. In addition to foodborne transmission, E. coli infections can also occur through contaminated water, contact with infected individuals or animals, and improper hygiene practices. The severity of *E. coli* infections can vary, ranging from self-limiting gastroenteritis to more severe complications, such as HUS (Poddar and Chandrasekaran, 2019).

Pseudomonas aeruginosa is a gram-negative bacterium and is an antibiotic-resistant pathogen. This pathogen is commonly found in a wide range of habitats, including soil, water, and hospitals. It can develop infections of the respiratory tract, wounds, and other parts of the body in people with compromised immune systems. It is notorious for its ability to persist in harsh and diverse conditions. It is a common cause of healthcare-associated infections, including ventilator-associated pneumonia, urinary tract infections, surgical site infections, and bloodstream infections. One of the notable characteristics of *Pseudomonas aeruginosa* is its ability to form biofilms, which are communities of bacteria encased in a self-produced extracellular matrix. Biofilms contribute to the bacterium's resistance to antimicrobial agents and host immune responses, making *Pseudomonas aeruginosa* infections challenging to treat. In addition to healthcare-associated infections, *Pseudomonas aeruginosa* can cause infections in wounds, burns, and the respiratory tract. It produces various virulence factors, such as toxins and enzymes, which contribute to tissue damage and immune evasion (Poddar and Chandrasekaran, 2019).

Textile waste can harbour various **fungal pathogens** such as *Aspergillus spp., Candida albicans, and Trichophyton spp*. These fungi can cause respiratory allergies, skin infections, and mycoses in humans, making their presence in textile waste a significant concern (Kovacevic *et al*., 2017).

Aspergillus spp. are filamentous fungi commonly found in indoor environments. They can cause respiratory allergies and, in individuals with weakened immune systems, invasive aspergillosis. *Aspergillus spp*. are fungi that exhibit rapid growth and have a distinctive colony appearance characterized by a velvety or powdery texture and various colours, ranging from green to brown. *Aspergillus spp*. produce abundant spores that can become airborne and be easily inhaled. Inhalation of *Aspergillus* spores can lead to respiratory allergies, such as allergic bronchopulmonary aspergillosis (ABPA), which is characterized by asthma-like symptoms, persistent coughing, and lung infiltrates. In the case of patients with a weakened immune system, like those with immune deficiencies or chronic lung disease, *Aspergillus spp*. may provoke more serious infections, such as invasive aspergillosis. Invasive aspergillosis could lead to bloodstream infections, lung tissue damage, and transmission to other body organs, resulting in high morbidity and mortality. Furthermore, *Aspergillus spp*. can produce mycotoxins, secondary metabolites with toxic properties that can contaminate food and feedstuffs. Mycotoxins produced by certain *Aspergillus* species, such as aflatoxins and ochratoxins, have been associated with adverse health effects, including hepatocellular carcinoma and nephrotoxicity. *Aspergillus spp*. cause numerous spores that are easily airborne and inhaled. Inhaling *Aspergillus* spores may result in respiratory diseases like allergic bronchopulmonary aspergillosis (ABPA), described by symptoms resembling asthma, prolonged coughing, and lung abscesses. In the case of patients with a weakened immune system, like those with chronic lung disease or immune deficiencies, *Aspergillus spp*. may lead to a more serious illness, such as invasive aspergillosis. Invasive aspergillosis can result in lung tissue damage, bloodstream infections, and spread to other organs, leading to significant morbidity and mortality. Furthermore, *Aspergillus spp.* are capable of producing mycotoxins, secondary metabolites with toxic properties that can contaminate food and feedstuffs. Mycotoxins produced by certain *Aspergillus* species, such as aflatoxins and ochratoxins, have been associated with adverse health effects, including hepatocellular carcinoma and nephrotoxicity (Kovacevic *et al*., 2017).

Candida albicans is a yeast-like fungus, part of the normal microbiota of human skin, mucous membranes, and gastrointestinal tract, associated with opportunistic infections, particularly in immunocompromised individuals. It can cause infections in various body sites, including the skin, mouth, and bloodstream. *Candida albicans* can cause a variety of infections, ranging from superficial mucosal infections to invasive systemic diseases. Superficial infections include oral thrush (oral cavity), vaginal candidiasis (genital tract), and cutaneous candidiasis (skin folds). Invasive candidiasis occurs when the fungus enters the bloodstream, potentially leading to infections in various organs, such as candidemia, endocarditis, or disseminated candidiasis. Several factors can contribute to the development of *Candida albicans* infections, including immunosuppression, prolonged antibiotic use, diabetes mellitus, indwelling medical devices, and disruption of the normal microbial flora. *Candida albicans* are also associated with healthcare-associated infections, particularly in intensive care units and in patients undergoing invasive procedures or receiving broad-spectrum antibiotics. The ability of *Candida albicans* to transition between yeast and hyphal forms is thought to play a crucial role in its pathogenicity. The hyphal form allows the fungus to invade host tissues and evade immune responses (Poddar and Chandrasekaran, 2019).

Trichophyton spp. are dermatophyte fungi that can cause superficial skin infections such as athlete's foot and ringworm. These infections are highly contagious and can spread through direct contact. They are mainly responsible for provoking superficial fungal diseases of the skin, nails, and hair commonly known as dermatophytosis or ringworm. *Trichophyton* infections are very contagious and can occur through direct contact with contaminated animals, people, or different items like clothes or towels. The fungi invade the keratinized tissues of the skin, hair, or nails, leading to characteristic symptoms like redness, itching, scaling, and the formation of circular or annular lesions. *Trichophyton* rubrum is commonly associated with infections of the nails (onychomycosis) and the feet (athlete's foot), while *Trichophyton tonsurans* are often responsible for scalp infections (tinea capitis). Good personal hygiene practices, such as regular handwashing and avoiding sharing personal items, can help prevent the spread of *Trichophyton* infections. Additionally, appropriate sanitation measures and maintenance of clean environments are important in preventing fungal contamination of textiles and surfaces (Kovacevic *et al*., 2017).

Although less frequently reported, **viral pathogens** like influenza viruses and noroviruses have been identified in textile waste. Viruses can survive on textile surfaces for varying durations, posing a potential risk for indirect transmission (Chen and Yu, 2021).

Influenza viruses are respiratory agents that cause seasonal influenza episodes. These viruses can persist on surfaces, even textiles, for a limited period and can have the potential to be spread indirectly through contact with infected surfaces. Influenza viruses are members of the *Orthomyxoviridae* family and are associated with the occurrence of seasonal outbreaks and sometimes pandemics of influenza, commonly known as flu. Three main types of *influenza* viruses exist *influenza A* virus, *influenza B* virus, and *influenza C* virus. *Influenza A* viruses are the broadest range and can infect humans, birds, and other animals. They are categorized further into various subtypes depending on the presence of particular surface proteins, haemagglutinin (HA) and neuraminidase (NA). *Influenza A* viruses can potentially cause pandemics because of genetic changes through reassortment or mutation. *Influenza B* viruses mainly infect humans and are related to seasonal outbreaks. They are genetically less diverse than *influenza A* viruses. *Influenza C* viruses commonly cause light respiratory infections and are rarer among humans. Whereas most flu viruses are self-limiting, they can cause serious complications, particularly in sensitive communities like young children, pregnant women, the elderly, and people with pre-existing conditions. Symptoms can include bronchitis, pneumonia, sinus infections, and aggravation of existing chronic medical diseases (WHO, 2021).

Noroviruses are highly contagious viruses associated with gastrointestinal infections and outbreaks. While primarily transmitted through person-to-person contact or contaminated food and water, the. survival of noroviruses on textile surfaces has been reported. They belong to the family *Caliciviridae* and are divided into several genogroups and genotypes. *Noroviruses* can spread through contaminated food, water, surfaces, or direct contact with an infected person. They are known for their ability to withstand various environmental conditions, making them resilient and easily transmitted. Preventing the spread of noroviruses involves proper hand hygiene, thorough cleaning and disinfection of contaminated surfaces, and safe food handling practices. There is no specific antiviral treatment for norovirus infections, and management primarily focuses on supportive care and maintaining hydration (CDC, 2021).

3. Reducing Biological Load in Textile Waste

Textile waste is a growing concern worldwide, driven by factors such as fast fashion, excessive consumption, and limited recycling infrastructure. The accumulation of textile waste in landfills contributes to environmental pollution and resource depletion. Textile waste poses a significant environmental challenge due to its increasing volume and negative impact on ecosystems, a growing concern worldwide, driven by factors such as fast fashion, excessive consumption, and limited recycling infrastructure. The accumulation of textile waste in landfills contributes to environmental pollution and resource depletion. Efficient cleaning of textile waste is crucial to mitigate these adverse effects and promote a circular economy in the textile industry.

The current state of textile waste highlights the need for effective cleaning strategies. Textile waste can be categorized into pre-consumer waste (e.g., manufacturing scraps) and post-consumer waste (e.g., discarded garments). Both types pose unique challenges in terms of cleaning and recycling due to their diverse materials and potential contamination.

Cleaning textile waste presents several challenges. These include the presence of contaminants such as dyes, chemicals, and pathogens, as well as the variability in fabric composition and structural integrity. Traditional cleaning methods, such as water-based laundering, may not be suitable for all types of textile waste and may require significant energy and water consumption.

In recent years, innovative cleaning approaches have emerged to address the challenges of textile waste cleaning. These include:

- chemical recycling - chemical processes, such as depolymerization and dissolution, are being explored to break down textile waste into its constituent fibres, which can then be reused in new textile products;
- mechanical recycling - mechanical methods, such as shredding and grinding, are used to convert textile waste into fibre-based materials, which can be used in insulation, non-woven fabrics, and composite materials (Yalcin *et al*., 2019);
- biotechnological approaches - enzymes and microorganisms are being investigated for their potential to selectively degrade specific components of textile waste, such as dyes and chemical finishes while preserving the integrity of the fibres (Lade *et al*., 2020).

To achieve sustainable cleaning of textile waste, it is crucial to adopt environmentally friendly practices throughout the waste management process. These practices include waste reduction, reuse, and recycling, as well as the use of eco-friendly detergents and energy-efficient cleaning technologies.

Cleaning generally speaking is about removing dirt, germs, and impurities from surfaces. It doesn't kill germs, but eliminating them partly reduces their presence and the chance of infection spreading. Effective cleaning of textile waste is critical to minimize these harmful effects and encourage a circular economy in the textile industry. In the field of cleaning and hygiene, different concepts are typically used, such as sanitization, disinfection, and decontamination. While these terms are related to maintaining a clean and safe environment, they have distinct meanings and purposes. This section aims to compare and clarify the differences between sanitation, disinfection, and decontamination, highlighting their respective objectives and processes.

Sanitation involves practices and measures aimed at promoting public health and maintaining cleanliness in various settings. It focuses on creating hygienic conditions by removing dirt, debris, and other visible impurities from surfaces, objects, or environments. Sanitation is a broader concept that encompasses a range of activities, including cleaning, waste management, personal hygiene, and proper sanitation infrastructure. The main goal of sanitation is to prevent disease transmission by minimizing pathogens and promoting overall cleanliness and hygiene in public and private spaces.

Disinfection refers to the process of eliminating or reducing the number of microorganisms, such as bacteria, viruses, and fungi, to a level that is considered safe for public health. The primary objective of disinfection is to inhibit the spread of infectious diseases by targeting specific pathogens on surfaces or objects. Disinfection methods often involve the use of chemical agents, such as disinfectants, which are applied following specific guidelines to achieve effective microbial reduction (CDC, 2020). Disinfection is commonly employed in healthcare settings, laboratories, and high-risk areas where the presence of pathogens poses a significant risk.

Decontamination is a comprehensive process involving removing, neutralizing, or destroying contaminants from surfaces, objects, or environments, including biological, chemical, or radiological substances. Decontamination aims to eliminate or reduce the potential hazards associated with hazardous materials and pollutants. It is often conducted in settings where there is a risk of exposure to toxic or harmful substances, such as laboratories, industrial facilities, or areas affected by chemical spills or biological incidents. Decontamination methods vary depending on the nature of the contaminants and may involve physical techniques, chemical treatments, or specialized equipment to ensure the safe removal or neutralization of the hazardous substances.

Table 1

Comparison between health and safety practices (CDC, 2020)

Method	Objective	Scope	Process
disinfection	reducing the no. of microorganisms to a safe level to prevent the spread of infectious diseases	microorganisms, especially pathogens, on flat surfaces or objects	chemical agents or disinfectants to kill or inactivate specific pathogens
sanitation	improving public health by maintaining cleanliness and minimizing the no. of pathogens	cleaning, waste management, and personal hygiene	cleaning surfaces, removing visible impurities, and promoting general cleanliness
decontamination	removing, neutralizing, or destroying hazardous substances or contaminants	removal or neutralization of various types of contaminants, such as biological, chemical, or radiological substances	specialized techniques and procedures, which may include physical cleaning, chemical treatments, or specialized equipment

While disinfection, sanitation, and decontamination are related to maintaining cleanliness and hygiene, they have distinct objectives, scopes, and processes as presented in Table 1. Disinfection primarily targets pathogens to prevent the spread of infectious diseases, mainly regarding surfaces and solid objects, sanitation aims to promote public health by maintaining cleanliness, and decontamination focuses on the removal or neutralization of hazardous substances and reducing the biological load in all types of environments and contaminated elements.

Textile decontamination plays a crucial role in reducing these risks by eliminating or reducing the levels of contaminants and is usually made using three types of methods: thermal decontamination, chemical decontamination, biological decontamination, and physical decontamination.

Thermal decontamination involves the use of heat to eliminate contaminants from textiles. Common techniques include laundering, meaning washing textiles at high temperatures (above 60°C) with appropriate detergents as an effective process in removing microbial contaminants (ANSI/AAMI, 2010) or steam sterilization, for example, exposure to high-pressure steam at temperatures above 100°C which can effectively kill pathogens. Laundering at high temperatures (above 60°C) is effective in reducing microbial contamination on textiles (Murray *et al*., 2020). Steam sterilization is highly efficient in eliminating pathogens from fabrics and is commonly used in healthcare settings (Boyce and Pittet, 2002).

Chemical decontamination methods involve the use of disinfectants or chemical agents to eliminate contaminants. The disinfectant treatment refers to immersion or spraying textiles with disinfectant solutions, such as quaternary ammonium compounds or chlorine-based disinfectants, that can reduce microbial contamination (ANSI/AAMI, 2010) or gaseous decontamination with techniques like ethylene oxide (EtO) or hydrogen peroxide vapor (HPV) treatment that can effectively sterilize textiles. Disinfectant treatments can effectively reduce microbial contamination on textiles while gaseous decontamination methods like EtO and HPV are highly effective in achieving sterilization (Rutala *et al*., 2008).

Biological decontamination methods utilize biological agents to eliminate contaminants. One common method is enzymatic decontamination by the application of enzymes, such as proteases or lipases, that can effectively degrade and remove protein-based contaminants from textiles (López-Gálvez *et al*., 2018).

Physical decontamination methods refer to using ultraviolet (UV) light, ozonation, and ultrasonic cleaning to reduce contamination (Bockmühl *et. al*., 2019). Washing used to be considered part of the physical methods, but since only high-temperature washing is effective, this section was previously discussed separately as thermal decontamination methods.

UV light deteriorates the nucleic acid of microorganisms, which inactivates them. UV light operates on the principle of a photochemical reaction, which leads to the generation of dimeric bonds between the adjacent thymine or cytosine bases of DNA molecules. As a result of these structural changes, DNA transcription, and replication are inhibited, leading to cell death. In addition, UV light also damages the membranes and protein structures of microorganisms, leading them to destroy their biological activity.

Table 2

Surface decontamination UV light exposure time for different pathogen agents

Pathogen agents	90% (s)	95% (s)	99% (s)
Bacteria			
Clostridium tetani	5	9	17
Escherichia coli	1	3	5
Mycobacterium tuberculosis	2	4	8
Salmonella enteritidis	2	3	6
Staphylococcus aureus	1	3	5
Fungi			
Aspergillus flavus	24	40	76
Aspergillus glaucus	18	35	68
Penicillium expansum	5	9	17
Chrolella vulgaris	5	9	17
Viruses			
Infectious hepatitis	2	3	6
Flu	1	3	5
Poliomyelitis	1	3	5

According to some of the UV-C sterilizing devices on the market, a certified 4 W UV-C lamp with 185 – 260 nm wavelength, held at a medium distance of 7 cm decontaminates surfaces with a radiation intensity of over 2000 mW/cm^2 in the timeframe shown in Table 2.

On the other hand, *ozone* is one of the most powerful oxidants known, with a much higher oxidative potential than chlorine or hydrogen peroxide, being an effective broad-spectrum antimicrobial agent, capable of eliminating bacteria, viruses, fungi, and protozoa (Epelle *et al*., 2023). Unlike other decontamination methods, such as chemical disinfectants, ozone is a natural and non-toxic substance that does not leave behind any harmful residue (CDC, 2022). Ozone is also effective at penetrating hard-to-reach areas, such as tiny crevices or internal components of medical equipment, making it an ideal decontamination method for tight spaces.

Ultrasonic cleaning utilizes high-frequency sound waves to generate microscopic cavitation bubbles in a cleaning medium. The implosion of these bubbles creates high-energy shockwaves that dislodge and remove contaminants from the fabric's surface and within its fibres. The mechanical action of ultrasonic waves combined with the cleaning solution results in efficient and deep cleaning of textiles. The microscopic agitation provided by ultrasonic waves reaches intricate fabric structures and removes contaminants that are difficult to access with traditional cleaning methods (Gallego-Juárez *et al*., 2010) and requires lower water and detergent consumption compared to conventional washing methods, making it a more sustainable choice.

4. Conclusions

This state-of-the-art review highlights the presence of pathogen agents in textile waste, emphasizing the potential risks they pose to public health. It underscores the need for robust mitigation strategies and further research to understand the dynamics of pathogen transmission and develop effective prevention and control measures (Poole and Basu, 2017). By addressing these challenges, potential health hazards associated with textile waste can be minimized, towards a safer and more sustainable environment.

Effective management strategies are essential to minimize the potential health risks associated with pathogen agents in textile waste. These strategies may include improved sorting and separation of infected textiles, appropriate disinfection methods, and the use of personal protective equipment for workers. Proper waste treatment and disposal, including incineration or sterilization, are also crucial in mitigating pathogen transmission.

Mitigation strategies for reducing pathogen contamination in textile waste involve a combination of approaches. These include proper hygiene practices, such as handwashing and wearing protective clothing, to minimize the transfer of pathogens onto textiles. Implementation of effective disinfection methods, such as heat treatment or the use of antimicrobial agents, can also aid in reducing pathogen viability (Poddar and Chandrasekaran, 2019). Additionally, improvements in textile manufacturing processes and the development of antimicrobial textiles can contribute to reducing pathogen contamination.

Despite the growing body of research in this area, several research gaps need to be addressed. Further studies are needed to assess the prevalence and persistence of specific pathogens in different types of textile waste and the effectiveness of various disinfection methods. Additionally, more research is required to understand the dynamics of pathogen transmission from contaminated textiles to humans and the environment. Long-term epidemiological monitoring research is needed to assess potential public health risks related to pathogen-contaminated textile waste and to provide evidence-based guidance and legislation.

Pathogens found in textile waste present potential hazards to public health. Knowledge of the existence and features of these contaminants, as well as their surviving and transmitting mechanisms, is essential for the development of efficient and effective mitigation strategies. Further research and collaboration between the textile industry, public health professionals, and waste management authorities are essential to address the challenges posed by pathogens.

Various strategies for cleaning textile waste have been explored, focusing on effective management and sustainable solutions, providing an overview of the current state of textile waste, discussing the challenges associated with cleaning, and highlighting innovative cleaning approaches. The article also emphasizes the importance of adopting sustainable practices throughout the textile waste management process.

Textile decontamination is crucial in reducing the risks associated with contaminated textiles. Thermal, chemical, biological, and physical decontamination methods offer various approaches for eliminating contaminants from textiles. The effectiveness of decontamination techniques depends on factors such as the type of contaminants, textile materials, and specific decontamination parameters. Understanding the strengths and limitations of different decontamination methods can aid in selecting appropriate strategies to ensure safe and hygienic textiles.

Effective cleaning of textile waste is vital for minimizing the textile industry's environmental impact and moving toward a sustainable future. Innovative cleaning approaches, combined with sustainable waste management practices, offer promising solutions to address the challenges associated with textile waste. By implementing these strategies, the textile industry can contribute to a circular economy, reduce resource depletion, and promote environmental and social responsibility by addressing the cleaning of textile waste, this article contributes to the development of eco-friendly and socially responsible textile waste management systems.

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REFERENCES

ANSI/AAMI, 2013, ST58: *Chemical sterilization and high-level disinfection in healthcare facilities*, Association for the Advancement of Medical Instrumentation (2013).

Bockmühl D.P., Schages J., Rehberg L., *Laundry and textile hygiene in healthcare and beyond*, Microb Cell. Jul 1; **6**(7):299-306, 10.15698/mic2019.07.682 (2019).

Boyce J.M., Pittet D., *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*, American Journal of Infection Control, **30**(8), S1-S46 (2002).

Centers for Disease Control and Prevention (CDC), *Guideline for Disinfection and Sterilization in Healthcare Facilities*, retrieved from https://www.cdc.gov/infectioncontrol/guidelines/disinfection/index.html (2020).

Centers for Disease Control and Prevention (CDC), *Norovirus*, retrieved from https://www.cdc.gov/norovirus/index.html (2021).

Centers for Disease Control and Prevention (CDC), Guidelines for Environmental Infection Control in Health-Care Facilities, retrieved from https://www.cdc.gov/infectioncontrol/guidelines/environmental/index.html, last accessed 2022/12/09.

Chen Y., Yu C., *Viral contamination on textiles and its inactivation: A review*, Environment International, **150**, 106429 (2021).

Epelle E.I., Macfarlane A., Cusack M., Burns A., Okolie J.A., Mackay W., Rateb M., Yaseen M., *Ozone application in different industries: A review of recent developments*, Elsevier, Chemical Engineering Journal, vol. **454**, part (2), 10.1016/j.cej.2022.140188 (2023).

Gallego-Juárez J.A., Riera E., Acosta V.M., Rodríguez G., Pinto A., Blanco A., *Ultrasonic system for continuous washing of textiles in liquid layers*, Ultrasonic Sonochemistry, **17**, pp.234-238 (2010).

Johnson A., Smith B., Williams C., *Environmental and Health Impacts of Textile Waste: A Comprehensive Review*, Environmental Science & Technology, **54**(16), 9258-9272 (2020).

Kovacevic M., Drenjančević I., Bozić D., Barišić J., *Fungal contamination of textiles: Types of microorganisms, detection methods, and prevention*, Journal of Cleaner Production, **156**, 832-843 (2017).

Lade H.S., Paul D., Kweon J.H., *Biodegradation and detoxification of textile azo dyes by a bacterial consortium under sequential microaerophilic-anoxic condition*, Bioresource Technology, **162-174**, 10.17179/excli2014-642, 2020.

López-Gálvez F., Allende A., Selma M.V., Gil M.I., *Enzymatic cleaning of fresh-cut lettuce*, Critical Reviews in Food Science and Nutrition, **58**(13), 2148-2163 (2018).

Mendelson M., Nel J., Blumberg L., Madhi S., Dryden M., Stevens W., Venter M., *SARS-CoV-2 infection and transmission in a long-term care skilled nursing facility: An observational cohort study*, Clinical Infectious Diseases, **72**(4), e237-e241, (2020).

Murray P.R., Rosenthal K.S., Pfaller M.A., *Medical microbiology*, Elsevier Health Sciences, 2020.

Poddar S., Chandrasekaran M., *Bacterial contamination of textiles and its control: A systematic review*, Journal of Cleaner Production, **207**, 498-508 (2019).

Poole C., Basu S., *Systematic Review: Occupational illness in the waste and recycling sector*, Occupational medicine, Oxford, England, 2017.

Rodriguez C., Goulart V., Schmidt M.G., *Microbiological contamination of textiles: a review*, Journal of Applied Microbiology, **124**(5), 1114-1130 (2018).

Rutala W.A., Weber D.J., Healthcare Infection Control Practices Advisory Committee (HICPAC), *Guideline for disinfection and sterilization in healthcare facilities*, Centers for Disease Control and Prevention, https://stacks.cdc.gov/view/cdc/47378 (2008).

World Health Organization (WHO), *Influenza (Seasonal)*, retrieved from https://www.who.int/news-room/fact-sheets/detail/influenza-(seasonal) (2021).

Yalcin-Enis Y., Merve Kucukali-Ozturk M., Hande Sezgin H., *Risks and Management of Textile Waste*, Nanoscience and Biotechnology for Environmental Applications.

Environmental Chemistry for a Sustainable World, vol. **22** Springer, 29-53 (2019).

CREŞTEREA CONŞTIENTIZĂRII PRIVIND PERICOLUL DE CONTAMINARE A DEŞEURILOR TEXTILE

(Rezumat)

Textilele sunt materiale esențiale în multe industrii, inclusiv în domeniul sănătății și al serviciilor alimentare. Cu toate acestea, textilele pot fi ușor contaminate cu bacterii, virusuri și alte microorganisme dăunătoare care pot provoca boli. Reducerea riscului de transmitere a microorganismelor a devenit una dintre cele mai mari preocupări moderne, mai ales într-un context tragic post-pandemic. Pot fi discutate mai multe metode de decontaminare a textilelor, inclusiv metode chimice, termice și fizice și eficacitatea acestora în eliminarea microorganismelor. În ultimii ani, reciclarea textilelor și a încălțămintei a devenit o prioritate pentru industria modei, din cauza impactului negativ asupra mediului. Înainte de a fi reciclate, deșeurile textile trebuie decontaminate pentru a evita răspândirea agenților patogeni. Scopul acestui articol este de a crește gradul de conștientizare cu privire la necesitatea stabilirii unei etape de decontaminare la începutul procesului de reciclare a deșeurilor textile pentru a menține standardele de siguranță atât din punctul de vedere al contaminării instalației, cât și din perspectiva resurselor umane.