ISBN: 978-93-94570-37-5

1. Antimicrobial Treatment of Textiles

Sachin M. Landage

Assistant Professor,
Department of Textiles,
D.K.T. E. Society's, Textile and Engineering Institute,
Ichalkaranji, Maharashtra India.

1.1 Introduction:

1.1.1 Skin Physiology and Textiles:

Clothing, such as a mosquito net or safekeeping textiles in the operating room, acts as a mechanical barrier to keep people safe from infestation, insect bites, protozoa, and microbes. Medical products may discover the use of these types of bandages. Textiles with antimicrobial properties are desirable in health-related business, trade, and care from pathogens. Infections and allergies are caused by fungi, bacteria, and insects. Other uses for antimicrobial textiles include air and liquid filtration, floor coverings, draperies, wall coverings, and so on. Body odor is caused by wetness on skin secretions, which release chemical substances required for living metabolic activity and bacterial decomposition. Malodor of the intimate garment area and armpit has been linked to bacteria capable of producing a variety of odorous compounds derived from androgens. Antimicrobial measures and a reduction in skin dampness can help to reduce malodor.

Cotton is the most common natural cellulosic fibre on tropical continents. Because it is absorbent, it allows microbes to grow. However, unlike cotton, viscose rayon is preferred for medical applications due to its preferred nature, which is free of natural impurities. Furthermore, wood pulp is preferred for many absorbent applications. As a result, for the current study, cellulose in its purified and fibrous form, viscose rayon, is preferred for ease of handling. Antimicrobial activity is used to inhibit the growth of bacteria. To avoid touching point sensitization and non-specific microflora problems, the antimicrobial should be applied to the fibrous assembly. If there are less critical reasons to use antimicrobials, inhibiting odor and discoloration of the cloth material is important. Consumers are increasingly interested in antimicrobial products, particularly those that are suspected of harboring microbes, such as floor coverings. The applications of such products will appear all over the medical, and filtration industries, as starting point additions to domestic items, and selected clothing items (like socks).

1.2 Antimicrobial Finishing of Textiles:

Microorganisms can be found almost anywhere in nature. Textiles, for example, are easily attacked or decomposed by colonies of microbes in large numbers. Textiles facilitate the spread of microbes such as odor-producing bacteria, pathogenic bacteria, mould, and fungi. These microbes have attached themselves to textile substrates. Furthermore, the surrounding atmospheric conditions on textiles are conducive to bacterial growth.

Microbes are both invisible and extremely adaptable. If the surrounding environment is favorable, these germs grow quickly through cell division. They divide and multiply at an alarming rate, following the simple progression of 1, 2, 4, 8, 16, 32, and so on.

1.2.1 Necessity of Antimicrobials:

Even with hygienic skin, microbes are always present on the body, with a distinct population ranging from 100 to 1000 microbes/cm2. The presence of microbes such as germs, yeast, fungi, and bacteria increases the risk of infection for the wearer. These microbial infections have a number of unfavorable consequences, including foul odours and stains caused by material discoloration. Microbes can compromise the textile's functional properties. Microbe growth in textiles has a number of negative consequences, not only for the textile but also for the consumer.

As natural fibers are more absorbent as compared to synthetic fibers, they are more susceptible to bacterial attack. Natural fibers’ structure retains water, oxygen, and nutrients, providing an ideal enriched environment for the rapid development of microbes. Furthermore, contact with a humanoid provides warmth, humidity, and nutrients, resulting in an ideal environment for bacterial growth.

Bacteria and fungi are the most dangerous organisms. Algae can grow on textiles in wet conditions. Fungi cause stains, fibre damage, discoloration, foul odours, and a slimy feel in textiles. Microbes may also grow due to the fabric's structure and chemical processes. A warm and humid environment exacerbates the problem.

As synthetic fibers got good resistance to the micro-organisms but the various type of low molecular weight finishes which are applied on the yarn or fabric leads to the development of micro-organisms, which causes the foul smell, staining on fabric, discoloration of dyes on fabric and sometimes if the attack is more severe this, it causes the loss in strength of the fabric.

1.2.2 Microorganisms:

Microorganisms are microscopic living organisms such as germs, yeast, fungi, and bacteria. These microbes can live in the mouth without causing an infection. Microorganisms are very small living organisms that cannot be seen by the eye. They are:

- Bacteria rod/spiral/ball, for example.
- Fungi are primitive plants, such as mushrooms.
- Seaweed is an example of a single/multicellular plant-like algae.
- Asthma is caused by dust mites found in human habitation

The market for antimicrobial finished textiles has grown dramatically in recent years. This development has been fueled by consumers' increased demand for clean, fresh, and sanitary clothing. Widespread research is being conducted to develop a new type of antimicrobial finish.

When bacteria attack human perspiration, it converts it into nasty stinking chemicals such as carboxylic acid, aldehydes, and amines, which leads to a foul odor. Deodorants and antimicrobial agents like triclosan have already been widely used with positive results all over the world for many personal hygiene products. The presence of various types of bacteria in the human body is prevalent in various parts of the human body and in people of various ages. Skin contamination by urine and other body fluid secreted by the body leads to moist conditions in garments that causes an increase in infections

1.2.3 Antimicrobial Textiles Have the Following Goals:

- To protect textiles from discoloration, staining, and quality deterioration.
- To control the development of microbes.
- To avoid cross-contamination from pathogenic microbes.
- To reduce the formation of foul odours, stop microorganism metabolism.

1.2.4 Requirements for Antimicrobial Finishing:

An ideal antimicrobial-treated textile should satisfy several requirements such as:

- It should be effective against bacterial and fungal species and not toxic to users.
- It should be quick to dry clean, launder, and heat press.
- The application should have no negative impact on the quality of the textile.
- It must be compatible with other application-specific finishing chemicals.
- It must be cheaply available and not emit hazardous compounds to the manufacturer as well as the environment.
- It should have no negative effects on non-pathogenic bacteria on the user's skin.

1.2.5 Classification of Antimicrobial Finishes:

Antimicrobial finishes are divided into 3 different groups.

- Rot proofing
- Hygiene finishes
- Aesthetic finishes

1.2.6 Types of Antimicrobials:

a. Leaching type (Conventional Antimicrobials):

- This type of antimicrobial finish penetrates textiles and spreads microbe mutations.
- The antimicrobial agent exits the garments, resulting in a circle of activity in which any microorganisms that come into contact are destroyed. As time passes, the antimicrobial agent's strength decreases, and it only harms the microorganism.
- The applied finish kills the microbes.
- The applied finish gradually loses its effectiveness.

b. Non Leaching Type (Bound Type):

- This type of finish regulates microbes.
- Products do not leave the garments and destroy the bacteria that are exposed to the garment's surface.
- The antimicrobial agent used in the finish is not consumed by the microorganism.
- By acting on the cell membrane, this type of antimicrobial agent kills microbes.
- These products are more durable as compared to leaching type of finishes.
- Bound type of antimicrobial finishes gives permanent finish for several number of washes.

1.2.7 Natural Antimicrobial Agents:

Natural antimicrobial finishing chemicals are sourced from plants and animal origin. Because of their biocompatibility and biological applications, they have received a lot of attention since ancient times. As a result, these agents are used in various sectors such as the pharmaceutical, biomedical as well as textile industries. The antimicrobial activity is also observed in marine animals like prawns, etc. Natural ingredients agents like Eucalyptus, Cinnamon, Chitosan, Neem Tulsi, Clove, Turmeric, Aloe Vera and many more exhibit antimicrobial activity.

a. Chitosan:

Research shows that a wide range of micro-organisms growth is inhibited by Chitosan for a broad spectrum of bacterial types. The activity of chitosan is determined by its molecular weight and more importantly the degree of deacetylation. The mechanism of activity of chitosan is based on mainly the primary amine groups present in it. The primary amine groups got the positive charge which reacts with the negative charges of the micro-organisms surface, which causes the changes in the cell of bacteria, resulting in intercellular oxygen linkages, leading to the death of the bacteria. Chitosan has been linked to cotton through the use of chemicals like DMDHEU, BTCA, and citric acid. Some of these chemicals are used in the resin finishing of cotton and cause hydroxyl group crosslinking of Chitosan to cotton. Chitosan can also be used in spinning dope to create fibers.

b. Sericin:

From Bombay Mori species of silk work, Silk Sericin is a protein derived. The amount of sericin derived is around 20–25% of silk protein. The majority of the sericin is removed during the pre-treatment operation - degumming at the silk processing stage. Sericin, on the other hand, has a high value because it is antimicrobial, oxidation resistant, UV resistant, and has moisturizing properties.

The recovered silk sericin also contributes to the reduction of environmental pollution. Furthermore, recovered sericin from degumming liquor is used in shampoo and other cosmetics moisturizing agents, and it is an important biomaterial for various textile applications. The application of silk sericin can also improve the functionality of some synthetic fibers.

c. Neem:

Neem (Azadtrachta Indica) is a popular plant in India that belongs to the Meliaceae family. It is a very promising agent for controlling microorganism growth and insect control, and the medicinal properties of the products are non-irritant to the skin. Many of these materials are cosmetics. Neem can be found in all parts of the plant, including the stem, bark, leaf, and root. It has antimicrobial and antifungal properties.

d. Aloe Vera:

Aloe Vera is a member of the Liliaceous family. It has traditionally been used to treat injuries and burns, as well as for cosmetics and other general health purposes. It is antifungal and antimicrobial, and it can be used in medical textile applications such as sutures, dressings, and bioactive resources.

e. Tulsi Leaves:

Tulsi, a member of the Libiatae family, is made up of the leaves of Ocimum sanctum Linn. Tulsi leaves have been used in traditional medicine as an antimicrobial, insecticide, and diaphoretic. The dipping method is used to apply Tulsi leaf extract to cotton fabric. It had a 73 per cent bacterial reduction, indicating maximum antimicrobial activity. Because the principles are of natural origin, they can serve as a suitable substitute for hazardous chemicals.

f. Tea Tree:

This is a well-known natural remedy for cuts, bites, burns, and other skin conditions. Tea tree oil contains over a hundred various complexes and is widely recognized as a natural curative product. It has dermatological, antiseptic, and antifungal properties and can be used to treat infections and infestations. Its oil is thought to have some of the world's best natural antiseptic/antifungal properties. The oil has antibacterial properties against a wide variety of bacteria. Its oil has also been shown to have antifungal and antimicrobial properties.

g. Eucalyptus:

Eucalyptus oil has very effective antimicrobial activity against infection-causing bacteria, fungi, and viruses. The oil deactivates the bacteria by using a 'target' that the oil has access to, while the interior cell alteration prepares the cell for its exponential growth period. However, as the cells enter the stationary phase, this target becomes 'inaccessible' to the oil.

h. Clove Oil:

Clove paste's bioactivity acts as both a protective and finishing agent for cotton textiles. Using DMDHEU-based resin improved the washing fastness of the finished textiles. Clove oil at 0.5 per cent concentration has a zone of inhibition of 17 mm, whereas cotton fabric treated with 1 per cent clove oil and resin has a zone of inhibition of 47 mm against Gram-positive bacteria.

1.2.8 Synthetic Antimicrobial Agents:

There are a plethora of compounds that can be used as antimicrobial agents. However, their attachment to the substrate significantly reduces their activity, and their incorporation into the textile surface or within the fibre limits their availability. Natural fibres offer an environmentally friendly textile, but more than 75% of natural fibres are finished with synthetic chemicals. Furthermore, the biocidal activity of the textiles is gradually lost during subsequent use and washing. These antimicrobial agents can be used to effectively regulate bacterial growth and sustainability in textiles.

a. Quaternary Ammonium Compounds (QACs):

In solution, QACs got a positive charge at the Nitrogen atom, which reacts with the negative effects and charges of micro-organisms, resulting in a mutation of the cell membrane of micro-organisms and interference with the cell wall of bacteria. The quaternary ammonium group remains undisturbed during the inactive stage of bacterial cells and retains its antimicrobial ability. QACs activity in the fabric is through to be due to an ionic interaction between the QACs and the anionic fibre surface. QACs have previously been applied to cotton, polyester, and nylon fabrics.

b. Polyhexamethylene Biguanides:

PHMB is a potent and broad-spectrum bactericidal agent with low toxicity that impairs cell membrane activity, and its activity increases in weight with increased levels of polymerization, resulting in greater biocide and possibly stronger binding to the textile surface. The cellulose fibres are treated with PHMB, followed by an after-treatment with a strong organic acid to increase durability and prevent fabric yellowing. A self-cross-linking resin and a catalyst are used in the PHMB treatment of synthetic fibres. PHMB can be applied using an exhaust technique on cotton at room temperature or a pad-dry-cure technique. PHMB reacts with cotton due to its cationic nature and is thought to be.

c. 2, 4, 4'-trichloro-2'-hydroxydiphenyl ether (Triclosan):

The antimicrobial agent Triclosan is effective against the most common bacterial species. It prevents microbial growth by inhibiting lipid biosynthesis. Triclosan, as a relatively small molecule, can be applied to polyester just like disperse dye and can be applied at various stages on polyester and nylon fibre at 5% of. The agent migrates to the exteriors of the treated textiles at a slow rate during the fabric's use, providing antimicrobial effectiveness.

Recent research indicates that Triclosan interfaces with the bacterial lipid production pathway, as well as Triclosan-incorporated polymers, may provide an ideal environment for resistant strains of bacteria to grow. Furthermore, it should only be used in a limited number of hospital settings. Because of the possibility of interaction with skin flora, percutaneous absorption, and total toxicity, safety is a primary concern that must be addressed. Because of these health and environmental concerns, several major retailers and European governments are concerned about the use of Triclosan in textiles and other related products.

d. Dyes:

Metallic dyestuffs, which are used to colour textiles, have antimicrobial properties. By selecting appropriate dyes, dyeing and antimicrobial finishing can be accomplished at the same time. Nowadays, dyes are made with antimicrobial activity in mind. For example, a new series of disperse dyestuffs produced by the reaction of sulphanilamidozonium chloride derivatives with Indian-1, 3-Dione demonstrated excellent dyeing and antimicrobial activity. To achieve the antimicrobial activity, simultaneous dyeing and finishing is a method of covalently conferring biocide to a dye via a linker. Novel cationic dyes, for example, were created by connecting the quaternary-ammonium group to the amino anthraquinoid chromospheres. Depending on their structure, such dyes demonstrated varying levels of antimicrobial activity.

e. Metals and Metal Salts:

Many heavy metals and heavy metal-containing compounds are toxic to microorganisms at low concentrations, whether in their atomic form or as compounds. Metals and metal salts kill microbes by reacting with and deactivating intracellular proteins. Although other metals, such as Cu, Zn, and Co, have been used as effective antimicrobial agents in textiles, Ag is by far the most commonly used in general textiles. Using electro-spinning, silver particles can be added to the polymer solution prior to extrusion. In the presence of water vapour, Ag diffuses to the surface of the fibre and forms Ag+ ions. The chemical and chemical and physical properties of the fibre, as well as the amount of silver present, can influence the rate of silver release.

In addition to direct integration, silver nanoparticles in a colloidal solution can be padded onto synthetic and cellulosic fabrics to achieve a long-lasting finish. Metal particles can be added to natural fibres during the finishing process, and several application techniques have been developed to improve penetration and durability. The cotton fabric was pre-treated with succinate acid anhydride, which acted as a legend for metal ions, increasing the successive adsorption of metallic salts (Ag and Cu2+) and providing very effective antimicrobial activity. The free aspartic and glutamic acid residues in protein fibres such as wool and silk are thought to be the most likely metal I binding sites. Tannic acid pretreatment improves the binding capacity even more by increasing the number of binding sites.

1.2.9 Application Methodologies:

a. By using Spun Additives:

The majority of synthetic fibre has no affinity. Antimicrobial properties can be provided by incorporating bioactive agents into the melt during melt spinning or in the spinning dope solution during wet or dry spinning. Various antimicrobial agents can be added to the polymer solution during the fibre or yarn manufacturing process, resulting in fibres with permanent antimicrobial properties. This is critical for textile manufacturers who want to avoid difficult subsequent operations when applying antimicrobial finishes to their products.

b. Padding:

With an expression of nearly 70-80 percent, the fabric can be padded with the antimicrobial agent. Certain cross-linkers, binders, and other additives can be used in conjunction with antimicrobial agents. Padding should be followed by air drying or stented curing.

c. Spraying:

Spraying the solutions with antimicrobial active agents is not normally recommended due to the risk of producing and inhaling large droplets. Nonetheless, if suitable containment facilities are available, the treatment can be applied by spraying. This method is especially suited to non-woven fabrics.

d. Microencapsulation:

The controlled release of antimicrobials from within the fibres appears to be a proven and viable technology for improving antimicrobial activity in synthetic fibres; however, this technique is ineffective for cotton. As a result, a new system can be defined as "fixation and controlled release." The capsules containing the antimicrobials are covalently fixed on the fibre using this system, and the antimicrobial effect may persist on cotton fabrics even after extensive laundering. The treated cotton surface would not have good antimicrobial efficacy if there was no release. When the release is too quick, the washing durability suffers. Furthermore, the capsules must be strong enough to withstand the processes commonly used in fabric treatment while also being small enough to be portable.

e. Polymer Modification:

This can be accomplished through the copolymerization of monomers containing bioactive functional groups. The advantage of this approach is that the bioactive elements become a part of the fibre, resulting in long-lasting effects. The disadvantage is that the technology is expensive because special polymerization plants are required.

1.2.10 Evaluation of Antimicrobial Finish:

Table 1.1: Evaluation of Antimicrobial Finish

Sr. No.	Test	Details
1.	**Antimicrobial activity of textile materials: AATCC TM 147**	The antimicrobial activity of treated textile materials against Gram-positive and Gram-negative bacteria can be determined quickly and qualitatively. The treated material is placed in nutrient agar with test bacteria streaked on it. After incubation, bacterial growth is observed visually. Zones of inhibition on and around the textile demonstrate antimicrobial activity.

Sr. No.	Test	Details
2.	**Antimicrobial finishes on textile materials: AATCC TM 100**	A quantitative method for assessing the antimicrobial activity of treated textiles. Serial dilutions and subsequent inoculations of sterile agar are used to determine the amount of bacterial growth in inoculated and incubated textiles. Bacteria of both Grams positive and negative are used.
3.	**Antimicrobial activity assessment of carpets: AATCC TM 174**	Methods are provided for the qualitative and quantitative determination of antimicrobial activity, as well as the qualitative evaluation of antifungal properties of carpet samples, using procedures and materials similar to those described above.

1.3 Bibliography:

1. E. Russell, *Textile Horizons*, Vol. 9/10, **(2002)**, P 7.
2. Mansoori G. A., Rohani. Bastami T., Ahmadpour Z. A., and Eshaghi, *Annual Review of Nano Research*, Vol 2., Chapter 2, **(2008),** P 1 -73
3. Abdel Naser M.B., Verma S., et al, *Bifunctional Textiles & The Skin*, Vol. 33, **(2006),** P 1
4. Hipler U.C., Elsner P., *Bifunctional Textiles & The Skin*, Vol. 33, **(2006),** P 1
5. Rao C. N. R., Muller A., and Cheetham A. K., *The Chemistry of Nanomaterials*: Synthesis, *Properties and Applications*, published by Wiley-VCH, Weinheim (2004).
6. Feynmann R.P., Miniaturization, Reinhold, New York **(1961).**
7. The scale of things Nanometre and more (**2012,** April) https://philebersole.files.wordpress.com/2012/04/nanotechnology.jpg
8. Schematic representation of the ‘bottom-up’ and top-down’ synthesis processes of nanomaterials, (**2015** September 26) retrieve from http://edavisndf2015.blogspot.in/2015/09/the-future-of-building.html
9. Yuan Gao, Robin Cranston, *Textile Research Journal*, Vol. 78(1), **(2008),** P 60.
10. Vyas S.K., Kandekar T.S., *Asian Textile Journal*, Vol. – 19 (5), **(2010),** 57.
11. Dorugade V.A., Bhagyashri k., *Man Made Textiles in India*, Vol.- 53(3), **(2010),** 89
12. Wasif A.I., Laga S.K., *AUTEX Research Journal*, Vol. 9(1), (**2009)** P 4.
13. *Technical Manual of the American Association of Textile Chemists and Colorists*, American Association of Textile Chemists and Colorists, Research Triangle Park, NC, 1999.
14. Rai M., Yadav A., Gade A., *Biotechnology Advances*, Vol. 27, **(2009),** P-76.