Antimicrobial Finish: Strengthening the Next Generation

By Dr Naresh M. Saraf, Dr Ashok G. Sabale and Dr Vaishali Rane, of Sarex, India

Introduction

Microbes such as bacteria, viruses, fungi and yeast are present almost everywhere. Human beings have an immune system to protect against accumulation of microorganisms but material such as textiles can easily be colonised by high numbers of microbes or even decomposed by them. Textiles are carriers of microorganisms such as pathogenic bacteria, odour-generating bacteria, mould and fungi.

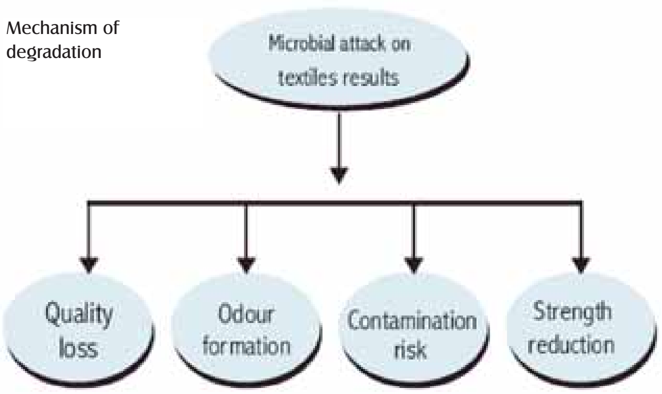
Bacteria-contaminated fabrics have been the major cause of skin infections and irritations. The ramification of a bacteria attack are clearly evident in many cases such as skin irritations, small babies suffering from diaper rash, foot infections, etc. Institutionalised individuals are more likely to develop skin infections than the people not confined to hospitals, nursing homes and similar establishments.

The most common method of preventing harmful and unpleasant build-up of bacteria in textile fabric has been disinfection by laundering or dry-cleaning. On the contrary, it has been found that bacterial damage increases with each laundering. Also, harmful bacteria are readily transferred from contaminated fabrics to clean fabrics during laundering. Intensive efforts have been underway, resulting in the development of new concepts such as antibacterial application in the realm of textile finishing.

Mechanism of Degradation of Textiles

All microbial actions involve enzyme action on the fibres, breaking them down into individual building units like glucose for cotton and amino acids for wool. Microbial decomposition of cellulose is brought about by the action of specific enzymes. The microorganisms secrete these enzymes only in the presence of cellulose. When they attack cellulose, a specific enzyme first liberates D-glucose, which is then utilised by microorganisms. Biological solubilisation of cellulose probably takes place exactly in two steps:

Mechanism of degradation

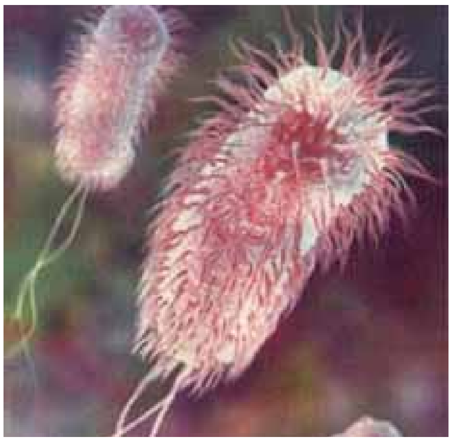


- Conversion of the native three-dimensional network of cellulose into linear polymer and
- Hydrolysis of 1, 4- -D-glucosidic linkage to form soluble sugars. Cellulolytic organisms depend on extra cellulase enzymes to produce soluble glucose.

The degradation of cellulose by enzymes is very similar to that which takes place in presence of acids, with the exception that the enzyme is constantly regenerated; the production of glucose is due to the enzyme-cellulase and cellobiase, and the glucose in turn ferments under the action of zymase.

All cellulolytic enzymes depend on extra-cellular enzyme to produce soluble glucose, which can be taken in through the cell wall. Bacteria lie on the surface of the fibre and appear to degrade the fibre from the surface inward to form hollowed-out areas. They do not penetrate at once to the centre of the fibre, but etch the surface so that it appears roughened or pitted.

In the destruction of wool, the active part of the microorganism is the proteolytic enzyme, which has the ability of hydrolysing the peptide linkage -CONH-. This hydrolysis is brought about by trypsin, which is composed of proteinase, polypeptidase and peptidase, but the tryptic enzymes are



always associated with enterokinase, an activator in the absence of which native proteins cannot be destroyed by trypsin. Tryptic enzymes cannot digest ordinary keratin unless the disulphide group has been ruptured, eg. by oxidation. The scaly layer of wool, which is free from tyrosine, is much more resistant than cortex or medulla.

Silk appears to be less susceptible than wool to enzymatic attack. A number of moulds that grow on raw silk only attack the gum, turning it yellow colour, whereas an attack on silk protein is accompanied by a brown colouration and an odour of ammonia, together with the loss of tensile strength, which is produced on all fibres when attacked by moulds and mildew. Bacteria do not develop very strongly on real silk.

What Is Antimicrobial Finish?

The term 'antimicrobial' comprises a series of particular agents that act against specific forms of microorganism, such as bactericide (antibacterial), fungicide (antifungals), insect proofers, mothproofers, herbicides, algicides, rot proofers and anti-dustmite products.

Functions of Antimicrobial Textiles:

1. To avoid cross infection by pathogenic micro-organisms.
2. To control the infestation by microbes.
3. To arrest metabolism in microbes in order to reduce the formation odour.
4. To safeguard the textile products from staining, discolouration and quality deterioration,

Characteristics of Antimicrobial Agents for Textiles

Antimicrobial agents can be considered as textile antimicrobial agents if they have the following characteristics:

a. **Stability:** Stability is determined by resistance to heat, light, ultraviolet rays and oxidizing agents. Very few chemical compounds possess all the characteristics. The agent must be stable as a compound and also when applied to the fabric. It must be stable not only for the estimated life of the finished goods, but must retain its stability through long period of storage.

b. **Efficacy:** The efficacy may be bacteriostatic/fungistatic or bactericidal/fungicidal. A large number of products actually destroy the microbes before they can grow and damage the fabric. Moreover, the compounds must be effective at a relatively small percentage, so as to enable the user to retain low weight add-on, and also to keep the cost within reasonable limits.

c. Toxicity: It must be non-toxic or of an extremely low order of toxicity. This is the most essential requirement of a good antimicrobial agent.

d. Odour: The antimicrobial compounds must not impart an unpleasant odour to the end item, particularly if it falls into the wear-apparel class. A number of antimicrobial agents possess unpleasant odour characteristics, while others are entirely free from this objectionable feature.

e. Colour: If the colour is of importance to the sale of the product, the antimicrobial agent must not discolour the treated material. This characteristic presents no great obstacle, since dye adjustments easily overcome any colour changes caused by these agents.

f. Hand: The antimicrobial agent must not significantly change the hand of the fabric, especially if the fabric is to be used in the manufacture of wearing apparel. Fabric should not get harsh hand after-treatment from antimicrobial agent.

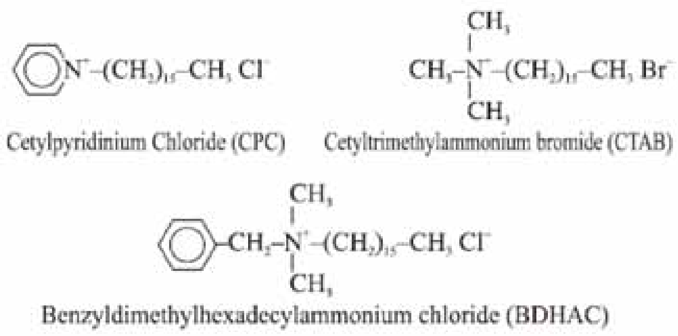
g. Chemical Effects: The antimicrobial agent must have no adverse chemical effects on the fabric processed. The tensile strength of the fabric must be maintained through long periods of use under all types of conditions.

Antimicrobial Agents for Textile

Quaternary Ammonium Compounds (QAC)

Quaternary ammonium compounds, particularly those containing chains of 12-18 carbon atoms, have been widely used as disinfectants. These compounds carry a positive charge at the N atom in solution and inflict a variety of detrimental effect on the microbes, including damage to cell membranes, denaturation of proteins and disruption of the cell structure. During the inactivation of bacterial cells, the quaternary ammonium group remains intact and retains its antimicrobial ability as long as the compound is attached to the textiles.

However the active quaternary ammonium site is covered by the dead bodies of microorganism and is therefore prevented from further contact with new cells. Thus, if the bacteria cells killed by the quaternary ammonium groups can be removed by laundering, the antimicrobial function of the QAC can be refreshed. The attachment of the QAC to a textile substrate is mainly by the ionic interaction between the cationic QAC and anionic fibre surface.



Ionic interaction chart

Antimicrobial Cationic Dyes

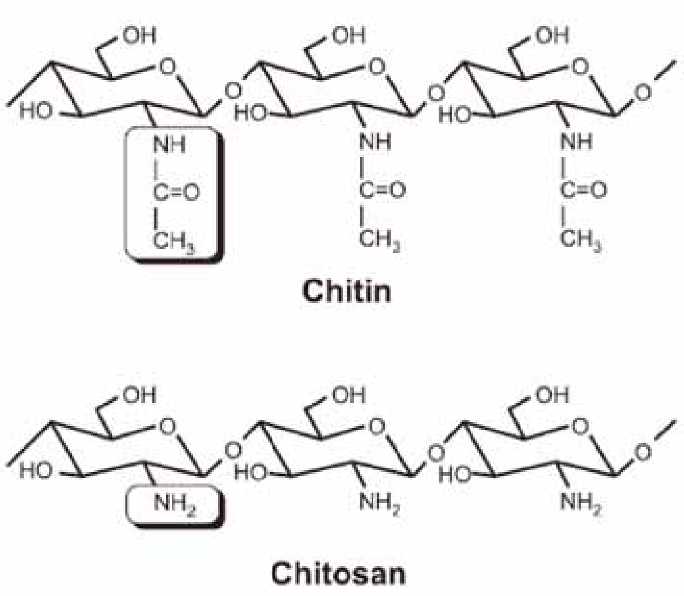
Combining the process of dyeing and finishing may pose the serious limitation and technological challenges in terms of compatibility of finishing chemicals and colorants in one bath. There has been a growing awareness in this area. One approach is a process wherein the dye is incorporated chemically with a different functional group so that the dyeing alone can give the required functional characteristics. Several antimicrobial cationic anthraquinone dyes have been prepared by traditional anthraquinone chemistry.

The number of carbon atoms in the alkyl chain has a decisive role in the antibacterial efficacy. Fewer than eight carbon atoms in the alkyl chain have led to very low antibacterial properties. It is also found that these dyes show higher antibacterial properties against gram negative bacteria than gram positive bacteria. The thermal and hydrolytic stability of these dyes decreases with the increase of alkyl chain lengths in the side chains containing quaternary ammonium group. They are especially useful for acrylic fibres.

Chitosan

Chitin, poly (1,4)-2-acetoamido–2 deoxy-D–glucose, is the most abundant natural polymer. Its chemical structure is similar to cellulose, differing in the second carbon position where the hydroxyl groups are replaced by amino groups. Chitosan is the deactivated derivative of chitin. Chitin and chitosan are widely distributed in animals and fungi and are the basic polysaccharides that are the major component of the shells of crustaceans such as crabs, shrimps and crayfish. Chitosan has many applications in the textile industry, including fibres, chitosan applications in wool pretreated with hydrogen peroxide, waste-water treatment, etc.

Due to the antimicrobial action of the amino group at the C – 2 position of the glucosamine residue, chitosan is also known to be an antimicrobial polysaccharide. The ability of the chitosan to immobilise microorganism derives from its polyatomic character. Its protonised amino groups block the protein sequences, inhibiting further proliferation of the microorganisms. Chitosan binds to the negatively charged bacterial surface, disrupting the cell membrane and altering its permeability. This allows the material to leak out of the bacterial cell, resulting in its death.



Chitin Chitosan

Polyethylene glycol

Cross-linked polyethylene glycol imparts antibacterial properties of significance to surgical-gown fabric. In addition, changes in the moisture related and thermal absorption and release properties have been noted. Because of the PEG, repellency is reduced. The finish has the potential to provide antibacterial properties and improve absorbency associated with increased comfort. It has been found that when PEG is applied on nonwoven fabric by foam-finishing technology, antimicrobial properties and surface wettability increase without impairing the repellency of the fabric.

Field of Application

Antimicrobial textiles inhibit the growth of microorganisms. It is convenient to sub-divide this general type of finish into three main groups:

- Rot proofing is an antimicrobial finish applied to give material protection, either long-term or short-term, against physical deterioration, eg. tents, awnings.
- Hygiene finishes are concerned with the control of infection and unwanted bacteria; a specialised development is the prevention of dust mites, eg. bedding, mattresses, carpets
- Aesthetic finishes are used to control odour development and staining, eg. socks, underwear, linings

Improving Durability

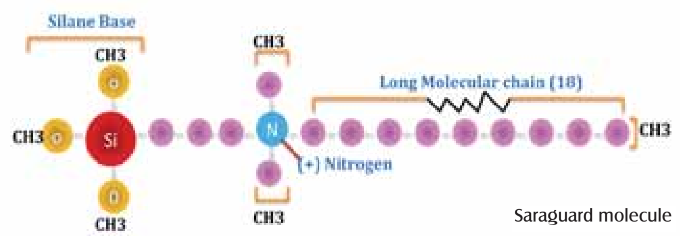
Methods for improving the durability of the finish can be classified in the following ways.

i) Insolubilisation of chemical reagents in or on the fabric
ii) Graft polymers, homo and copolymerisation technique
iii) Treatment of fabric with resin condensates or crosslinking agents
iv) Chemical modification by covalent bonding
v) Coating of fibre surface
vi) Microencapsulation of a chemical agent

At Sarex we have developed Saraguard-5700 antimicrobial agent for excellent resistance to microbes.

Unique Features of Saraguard-5700

- A durable antimicrobial for finishing of textiles
- Can be applied by padding, exhaust, soaking, spraying methods on any substrate
- Leach-resistant and non-migrating
- Effective against a broad spectrum of microbes such as Klebsiella pneumonia, Staphylococcus aureus and Escherichia Coli
- Works by contact method, ie. microbes are eliminated when these come in contact with Saraguard-5700
- Inhibits the growth of odour-causing bacteria and prevents the growth of mould and mildew



Saraguard molecule