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# A REVIEW ON DEVELOPMENT OF ANTIMICROBIAL AND LIQUID/BLOOD REPELLENT SURGICAL GOWN FOR HOSPITAL USAGE

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**Keywords:**

Antimicrobial, Liquid/blood repellent, Surgical gown, Bionanocomposite, Biodegradable

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**ABSTRACT:** Recently care regarding functional finishing of medical apparels such as liquid/blood repellent and antimicrobial has increased due to the risk of harmful microbes generation on these fabrics while coming in contact with fluids such as blood, sebum etc. Of the various medical textiles, surgical apparels are important textile products as they protect health care workers from microbial contamination. As consumers have become more aware of hygiene and potentially harmful effects of microbes, the demand for antimicrobial finished clothing is increasing. Different chemicals and heavy metal finished fabrics even though provide good liquid/blood repellent and antimicrobial activity, but these compounds cannot be used for the development of surgical gown due to factors like toxicity and non-biodegradability. Over the last few years, several attempts have been made to replace petroleum products with renewable and biodegradable components. Hence, fabric finished with chitosan (natural polymer)-herbal bionanocomposite are considered significant for fulfilling these objectives. This review discusses different protective textiles prepared with different antimicrobial and liquid/blood repellent finish used in medical textiles. It also sheds light on the development of bifunctional fabrics (as surgical gown) for health care workers in order to mitigate cross contamination.

**INTRODUCTION:** The most important criteria of health are sanitation and hygiene. They are very important parameters in medical textiles especially at the time of surgical and post-surgical operations [1]. The major sources of cross infection are the fabrics contaminated with bacteria and viruses when they come in contact with biological fluids such as blood, sweat etc [2, 3]. The hospital acquired infections are mostly based on postoperative infections.

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10 to 22% of patients undergoing surgical formalities develop postoperative infections [4, 5]. So, to protect the health care workers and patients from cross contaminations, surgical apparels must have antimicrobial and liquid/blood repellence properties. Out of so many, only cotton fabric shows the best performance as polyester and polyester/cotton blended woven fabric cannot give out the comfort ability to that extent to the wearer due to its compact and rigid structure.

Again, as the wet strength of cotton is high, its wash durability and ultimate longevity would be high enough. Of the various medical textiles, surgical apparels are important textile products as they protect health care workers from dangerous viruses such as Hepatitis B, HIV, etc.

These microbes can penetrate the surgical apparels and can easily interact with the skin of the surgeons as they are much smaller than the pore size of the fabrics. In order to extend a safeguard to the healthcare workers from invasion of such deleterious viruses, nonwoven fabrics are frequently used as surgical apparels in most of the foreign hospitals. However, the use of nonwoven fabrics is not practiced in Indian hospitals due to their high cost, less protective efficiency and no reusability. Most of the Indian hospitals use sterilized surgical gowns made up with cotton and polyester/cotton blended woven fabrics due to their stability against reusability which are not effective for avoiding cross contamination. Hence, suitable surgical apparel with antimicrobial, breathable and liquid/blood repellent properties with good moisture transport is essential for hospital usage.

Various antimicrobial agents and liquid/ blood repellents recurrently available in the market with a wide range of antimicrobial along with liquid/blood repellence properties under different trade names for medical apparels. These chemicals include heterocyclics with anionic groups, amines, formaldehydes, ureas and related compounds, phenols, thiophenols, onium salts, organometallics, iodophors, antibiotics, quaternary ammonium compounds (QAC), 2,4,4'- trichloro -2'-hydroxydiphenyl ether (Triclosan), chlorine containing N-halamines, peroxy acids and polyhexamethylene biguanides (PHMB). But most of them are very much toxic in nature and having problems regarding biodegradability [6, 7].

Nowadays, scientists of the medical textile industry are in search of suitable materials that can substitute the prevalent toxic chemicals [8]. Recently, natural and herbal products like chitosan, *Aloe vera*, tea tree oil, tulsi, neem leaf extracts are gaining attention of the researchers for their low cost, eco friendliness and availability of resources. Nowadays, chitosan has proved itself a very effective antimicrobial bio-agent for medical apparel [9]. Extracts from different parts of diverse species of plants like seeds, roots, leaves, flowers, etc. also exhibit antibacterial properties. But the major problem lies with their poor wash durability due to its lack of bonding force with the fabric though they show good antimicrobial property after applying on cotton fabric [10].

In order to overcome the problems, the only way left with us is the chemical modification of the agents that lowers the surface energy that means they are to be applied on to cotton fabric in nano form. Again, it has been observed that [11] chitosan and herbal extracts alone in nano form show good antimicrobial property with significant wash durability without showing any improvement in liquid and blood repellency as they cannot form nano whiskers of appropriate length to develop the same. In order to cope up with the problems, it has been thought worthwhile to develop chitosan-herbal bionanocomposite so that each of the components can work synergistically for achieving the required nano composite along with significantly higher length of nano whiskers in view of the development of antimicrobial and liquid/ blood repellent surgical gown. In this review an attempt has been made through an exhaustive study to explore the development of surgical gown with antimicrobial, breathable and liquid/blood repellent properties for hospital usage.

**Medical Textiles:** Medical textiles are one of the important and emerging sectors of Technical Textile Industry (TTI) [12]. It has been growing rapidly and constantly demands new technological solutions for addressing issues and problems faced by medical professionals and patients. Medical textiles used for protection play an important and crucial role for infection control and maintaining hygiene [13]. This is an area which requires large amount of speciality finished products such as surgical clothes, uniforms, clothing, etc. There are consistent advancements occurring both in the field of medical sector and in textiles. Some of the technologies are integrated in the industries whereas others require time to build, fortify and get accepted. The increased demand with desired features for medical textiles will have a huge effect on comfort, quality and life expectancy of people [14].

In present times, medical textiles are finished with antimicrobial agents to kill bacteria. Some of the viruses like HIV are not destroyed by antimicrobial agents. So, penetration of these viruses through surgical fabric should be avoided [15]. This is done by finishing of medical textile products with liquid/blood repellent chemicals to protect against hazardous viruses.

The global medical textiles market size was estimated at USD 21.2 billion in 2021 and is expected to hit around USD 29.1 billion by 2030 at a compound annual growth rate (CAGR) of 3.58% from 2022 to 2030 [16] **Fig. 1.** The demand for medical-grade textile products is expected to grow on account of the increasing awareness regarding better healthcare services and efficient medical treatments. The consumption of different categories of medical textile [17] is shown in **Table 1.** The growing use of medical textile-based implantable goods, such as artificial ligaments, tendons, and body part enhancements is expected to drive the market. The burgeoning aging population globally is expected to boost the number of surgeries for knee and joint replacement, in turn, driving the usage of implantable goods, thereby driving the market [18].

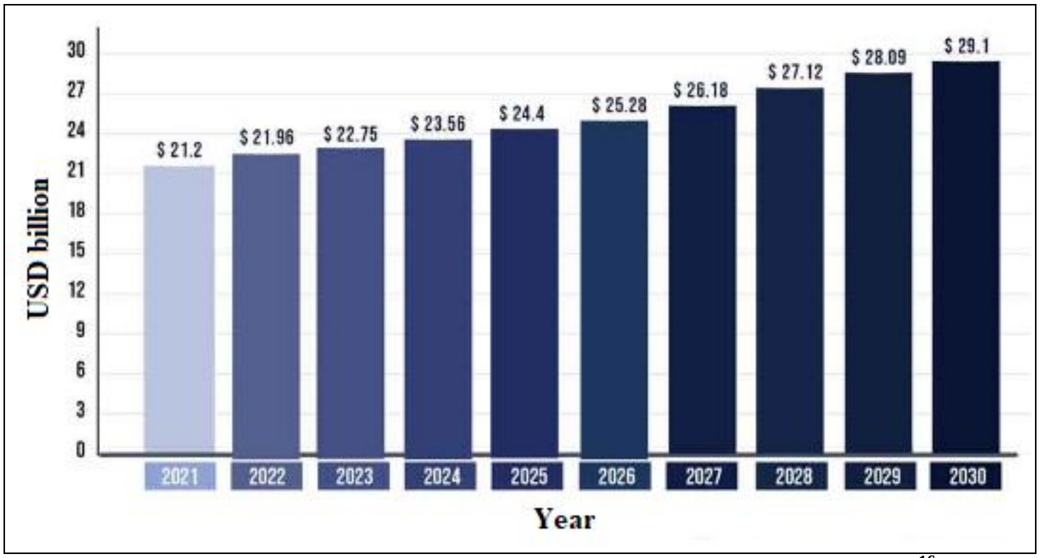


**FIG. 1: MEDICAL TEXTILES MARKET SIZE FROM 2021 TO 2030 [16]**

**TABLE 1: CONSUMPTION OF DIFFERENT CATEGORIES OF MEDICAL TEXTILES [17]**

| | | Market potential ( Rs Mn) | | | |
|---|---|---|---|---|---|
| **S. no.** | **Medical textile product** | **2005** | **2010** | **2015** | **2020** |
| 1 | Medical devices and implants | 1190 | 2104 | 2978 | 3765 |
| 2 | Incontinence diapers | 605 | 1070 | 1502 | 1897 |
| 3 | Sutures | 3160 | 5587 | 5617 | 5783 |
| 4 | Healthcare textiles | 1491 | 2635 | 3753 | 4961 |
| 5 | Sanitary napkins | 4819 | 8519 | 13951 | 27167 |
| 6 | Surgical dressing | 5828 | 10302 | 19802 | 28753 |

**Protective Textiles Used in Medical Textiles:** Medical textile products like bandages, surgical mask and surgical gowns are treated by special finishes so that it can turn to protective textile material to the wearer [19]. Medical protective textiles particularly fabrics are developed by finishing of fabric with antimicrobial and liquid/blood repellent chemicals like chitosan and fluoropolymers [20], organosilane modified fibres [21], silver ions with isocyanate-based cross linker and fluorocarbon [22] and fluoropolymer 'Clariant Nuva SRCN liq.' with 'Zydex zycrobial' non-leaching type antibacterial finish, a quaternary ammonium salt based compound [23]. There are two methods of chemical finishes applied over fabric to develop medical protective textiles. They are nothing but antimicrobial and liquid/blood repellent finishing [24].

**Antimicrobial Finishing:** In recent times, textile materials expected to act smart in apparel and in technical textile application. To impart functionality, various finishes are applied to the fabrics. Among the various finishes, antimicrobial finishing is necessary for medical textile materials owing to its need based demand [25].

It is hardly possible for bacteria to move from one corner to another smoothly. Some carriers like dust, lint, skin particles or liquids are essential for their movement. The health care workers are considered as one of the most important source of bacteria/virus. The staff and the patient are the main source of wound infection. The possibility of infection increases due to transmission of microbes through liquid or blood coming out of scars [26] **Fig. 2.**

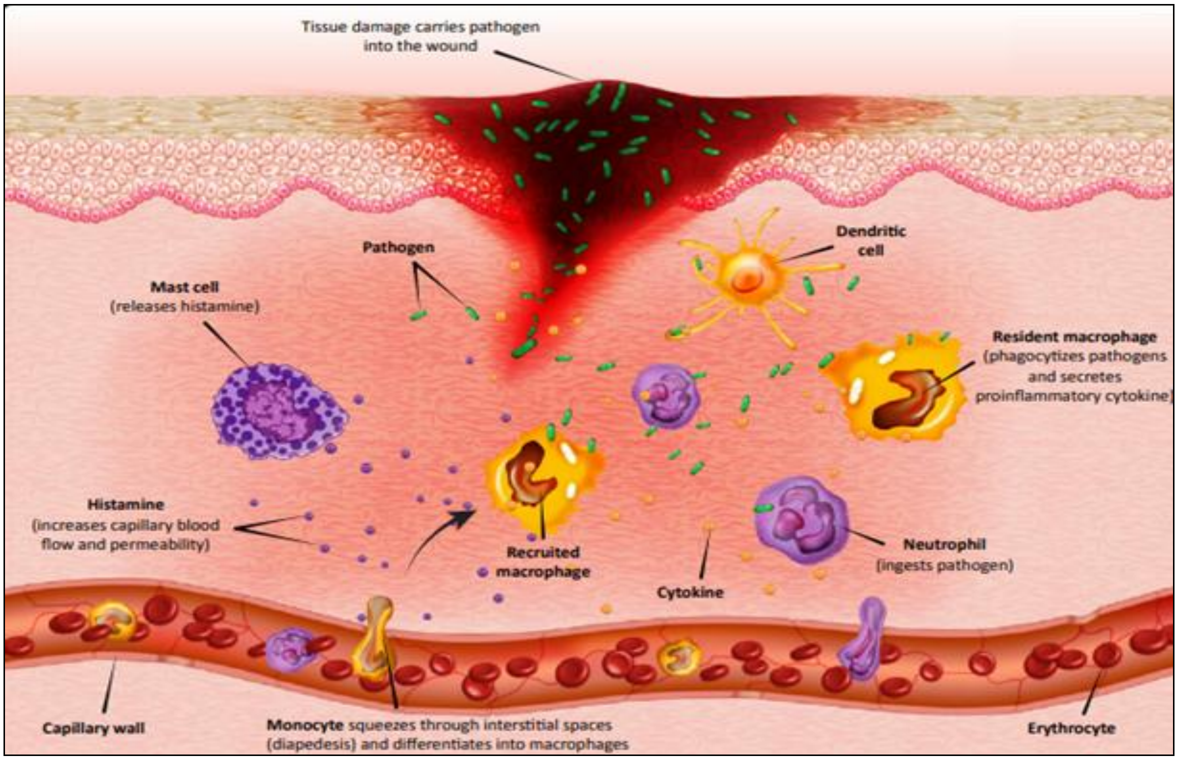


**FIG. 2: EMERGENCE OF WOUND INFECTION DUE TO TRANSMISSION OF MICROBES THROUGH LIQUID OR BLOOD COMING OUT OF SCARS [27]**

**Need for Antimicrobial Finishing:** The minimum nutritional requirements for microbial multiplication and growth are moisture, carbohydrate, protein and inorganic solvents [28]. Textile materials are considered as one of the most important medium for propagation of infection. To control the infestation of microbes' antimicrobial treatment for textile materials is necessary [29].

**Chemicals Used for Antimicrobial Finishing:** Generally, chemicals used for antimicrobial finishing can be separated in two categories: antimicrobials with controlled release or leaching type and bound or non-leaching type [30] **Fig. 3**. The antimicrobial agents that belong to leaching type category does not form strong bonds with the textile substrate.

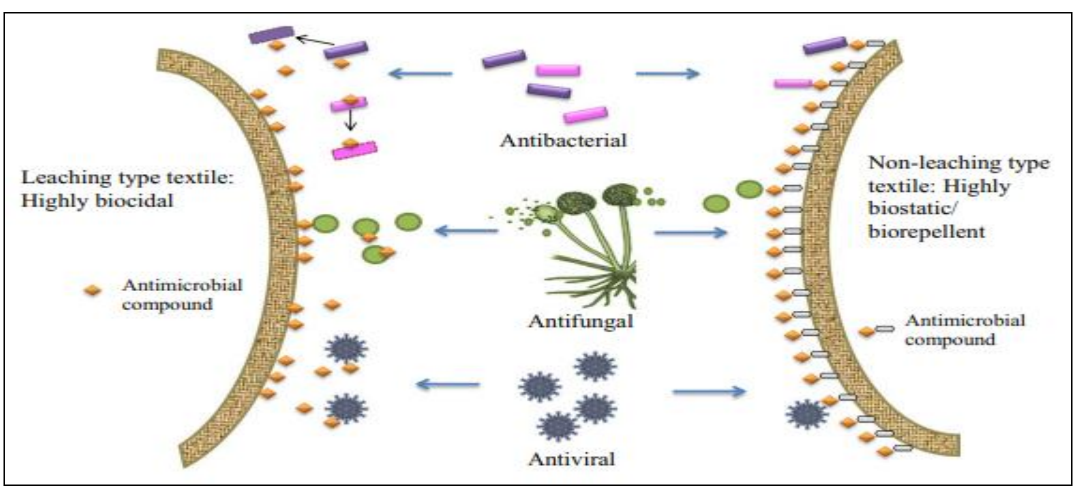


**FIG. 3: TYPES OF ANTIMICROBIAL TEXTILE: LEACHING TYPE MAY BE MORE BIOCIDAL BY RELEASING THE ACTIVE AGENTS AS COMPARED TO NON LEACHING TYPE, WHICH MAY BE BIOSTATIC OR BIO-REPELLENT AS IT STRONGLY BINDS THE ACTIVE AGENTS [31]**

The chemical species responsible for biocidal activity are released slowly from the treated fabric surface, thus killing the microbes surrounding the agent. Advantages of leaching antimicrobials effect are their superior antimicrobial activity than compounds based on other modes of action on the same fabric under similar environmental conditions. The flip side is that this type of antimicrobial agents in textile substrate is depleted eventually and loses its effectiveness [32]. Efficiency is having a direct correlation with the dosage of antimicrobial agents used. So, the application quantity of the antimicrobial agent should be optimized [33]. Metal (e.g., silver), Metal salts (e.g., silver nitrate), and halogenated phenols (e.g., triclosans) are examples of antimicrobial agents that utilize the leaching mechanism. The antimicrobial agents that belong to bound or non-leaching type category are chemically bound to the textile substrate. Hence, the antimicrobial can act only on the microbes that are in contact with the treated textile's surface. By virtue of its binding nature, these antimicrobials are not depleted and therefore potentially may have higher durability. However, compounds on a treated fabric might get abraded or deactivated with long-term usage and lose their durability. The antimicrobial agents listed under this category are Quaternary Ammonium Compounds (QACs) [34, 35] **Fig. 4**, triclosan [36] **Fig. 5,** polyhexamethy- lene biguanides (PHMB) [37] **Fig. 6**, chitosan [38] **Fig. 7** and N-halamines [39] **Fig. 8**.

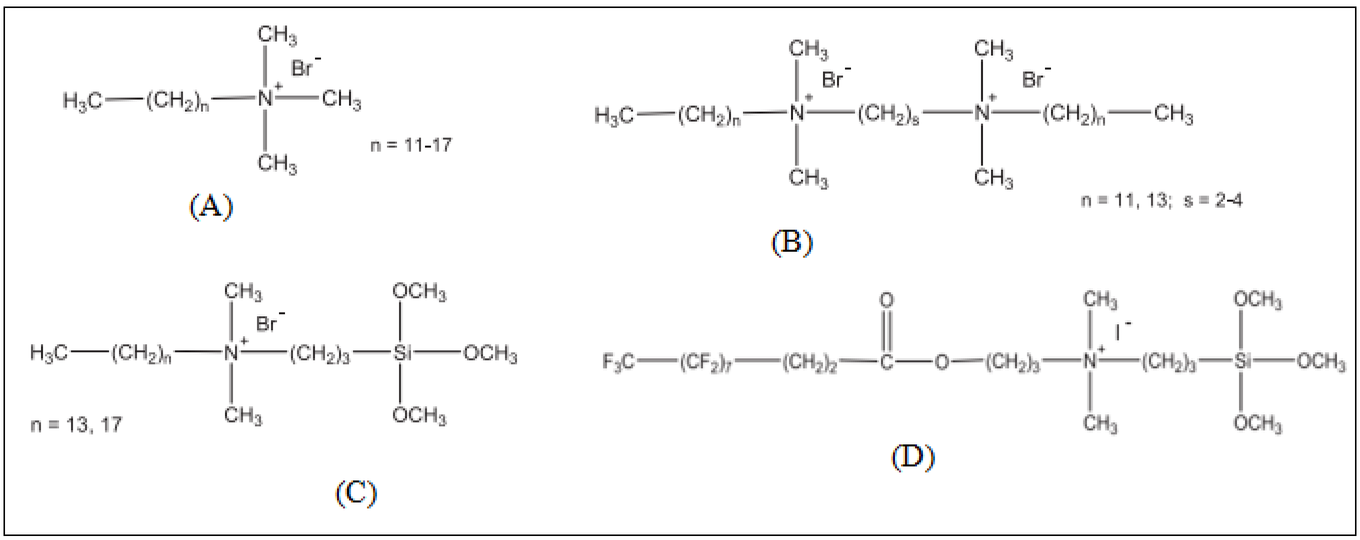


**FIG. 4: QUAQTERNARY AMMONIUM COMPOUNDS (A) ALKYL TRIMETHYL AMMONIUM BROMIDE (B) ALKANEDIYL-α, ω- BIS(DIMETHYL ALKYL AMMONIUM BROMIDE (C) ALKYL-DIMETHYL-(3(TRIMETHOXYSILYL)-PROPYL) AMMONIUM BROMIDE (D) PERFLUOROOCTYLATED QUATERNARY AMMONIUM SILANE [34]**

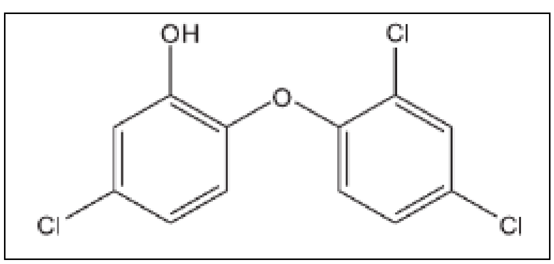


**FIG. 5: CHEMICAL STRUCTURE OF TRICLOSAN [36]**

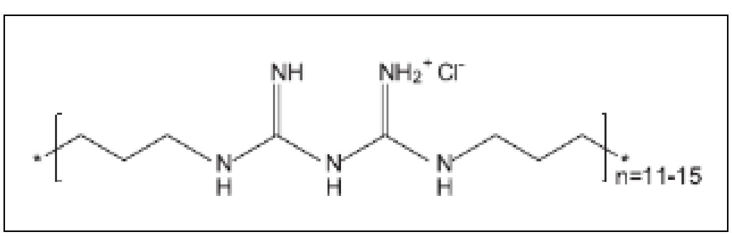


**FIG. 6: CHEMICAL STRUCTURE OF POLYHEXAMETHYLENE BIGUANIDE [37]**

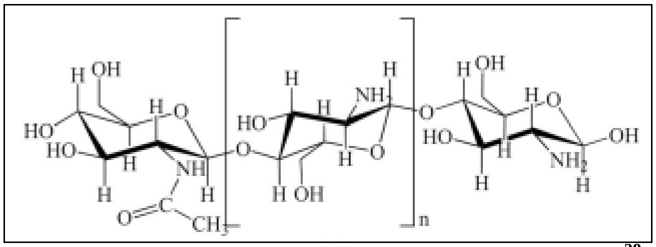

FIG. 7: CHEMICAL STRUCTURE OF CHITOSAN [38]

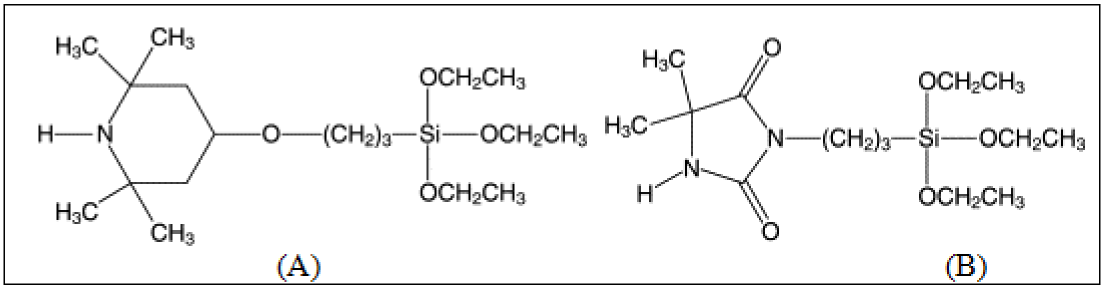


FIG. 8: CHEMICAL STRUCTURE OF N-HALAMINE SILOXANES: (A) 4-(3-TRIETHOXYSILYL PROPOXYL)-2,2,6,6- TETRAMETHYL PIPERIDINE (B) 5,5- DIMETHYL- 3-(3´- TRIETHOXYSILYL-PROPYL) – HYDANTOIN [39]

**Liquid/Blood Repellent Finishing:** Liquid/blood repellent finishing of cotton fabric is an important finishing process which prevents penetration of liquid/blood through the fabric without affecting its comfort. These are commonly termed as durable water repellents (DWRs) [40, 41].

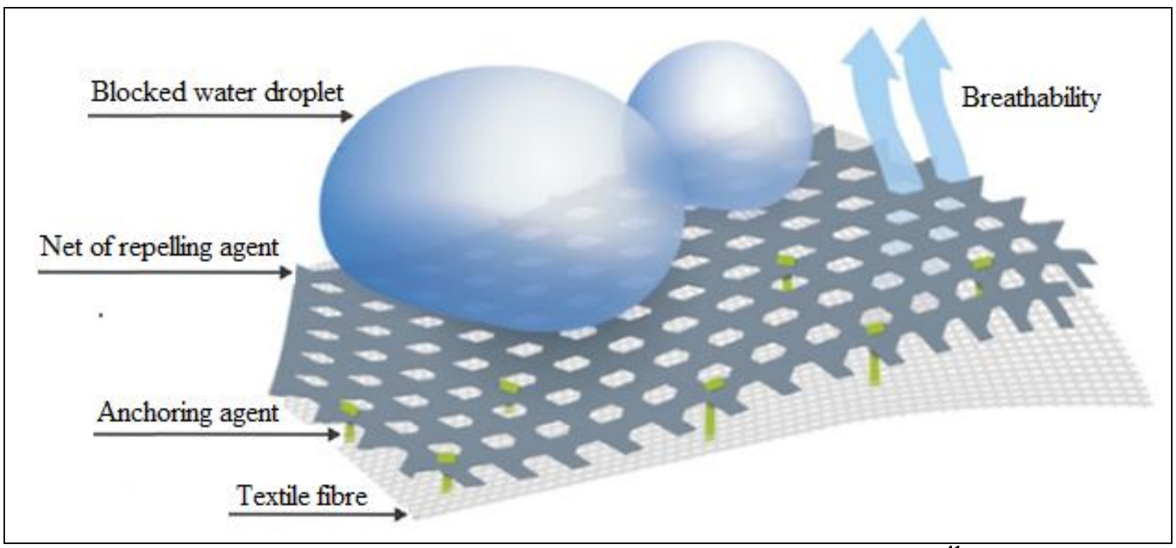


FIG. 9: DURABLE WATER REPELLENT COTTON FABRIC [41]

The existence of intermolecular attractive forces of polarity and hydrogen bonding enhances easy wetting of fibre by water offering little resistance to snow, rain, residual saline, liquid medicines etc. and blood for outerwear garments [42]. These fabrics are made water repellent by adding various water repellent chemicals to the fabric either chemically or with mechanical coating. The outer surface of the fabric is covered with the water repellent compounds having hydrophobic groups. The hydrophobic groups repel liquid (water) molecules forming a low energy surface [43].

The formation of chemical bonds between the fibre and water repellent chemical should be strong to produce durable water repellency. Pyridinium compounds, chromium based metal complexes and N-methylol based products accomplish the durable chemical bond formation. These products provide durable water repellent performance. But these compounds are hazardous and toxic to the environment which is limiting their production [44].

**Need for Liquid/Blood Repellent Finishing:** Liquid/blood repellent finishing commonly known as simply liquid or water repellent finishing is required for clothing, home, rain water, medical bandages, surgical gowns and surgical face mask to provide repellency against liquids for various applications [45]. Especially medical textile product needs liquid repellent finish to avoid infection causing pathogens, which comes from penetration of body fluids and blood through the fabric [46]. Water repellent finishing is a treatment applied to textile substrates that does not allow the passage of water droplets through the fabric but allows the passage of water vapour. This fabric is called as breathable fabrics [47].

**Chemicals for Liquid/Blood Repellent Finish:** Aluminium and Zirconium compounds are two of the oldest water repellent agents having hydrocarbons [48]. The fabric has to be soaked in alkaline aluminum acetate on the fabric surface which imparts repellency to the fabric. Coating of the fabric with hydrophobic substances such as paraffin wax is the earliest method of preparing water repellent fabric. Paraffin wax is applied to the fabric by rubbing a solid wax on the fabric or as a solution in a suitable organic solvent such as benzene or by spraying wax in the molten state onto the fabric [49]. Fabric treated with chrome complex solution followed by drying to remove water molecules and curing at 150-170$^0$C at which complete polymerization of complex occurs at – Cr – O – Cr – linkages and covalent bonds formed with polar groups or negatively charged groups of fibre surface [50]. Since the chromium part of the complex is covalently linked to the fibre surface, the fatty acid portion i.e. the stearate group, is oriented outward from the fibre surface. The oriented stearic acid group imparts water repellency to the resulting product. When heated to higher temperatures like 149$^0$C, quaternary ammonium pyridinium compounds react with cellulose, forming an ether linkage between the hydrophobic part of the pyridinium compound and cellulose. 1-(stearamidomethyl) pyridinium chloride reacts with cellulose to produce water repellent fabric with the attachment of hydrophobic stearyl groups to cellulose. Silicon compounds are found to be good water repellents. When the fabric is exposed to a mixture of dichloromethylsilane and trichloromethylsilane in vapour form followed by neutralizing with ammonia gives good water repellency fabric. Fluorochemical repellents have much lower surface energies than hydrophobic and silicone repellents imparting both water repellency and oil repellency together [51].

**Medical Textile Innovations:**

**Antimicrobials and Fluid Repellency:** Antimicrobial finishes on cotton fabric have been widely explored for hospital applications to reduce the risk of healthcare associated infections

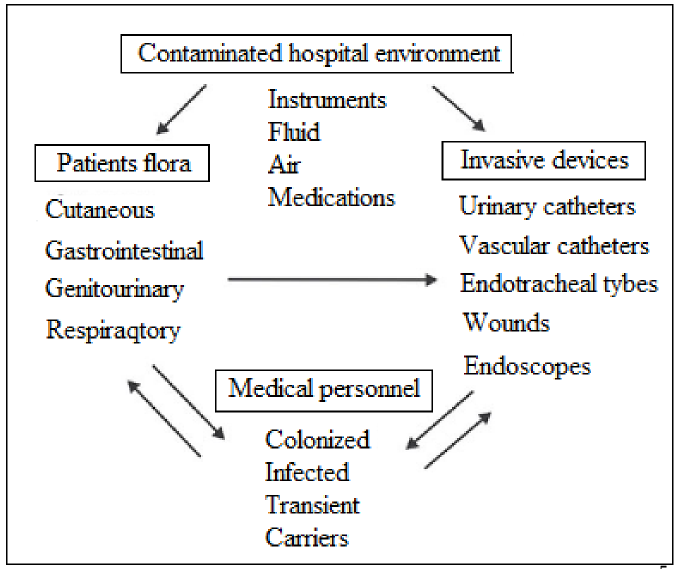


**FIG. 10: HEALTHCARE ASSOCIATED INFECTIONS [5]**

(HAIs) [52] **Fig. 10**. Researchers have investigated various antimicrobial agents, including quaternary ammonium compounds (QACs), triclosan, polyhexamethylene biguanides (PHMB), chitosan, N-halamines and silver nanoparticles [53]. These agents have shown effectiveness against a range of microorganisms, including bacteria, viruses and fungi.

Liquid repellent finishes have also been developed to prevent the penetration of bodily fluids and other liquids, reducing the risk of cross-contamination. Fluoropolymer-based coatings [54] and silicon based treatments [55] have been shown to be effective in repelling liquids.

Combining antimicrobial and liquid repellent finishes can provide enhanced protection against HAIs. A lot of work has been conducted on developing simultaneous antimicrobial and liquid/blood repellent finishing of medical apparels. Lee *et al.* [56] worked for the development of antimicrobial and liquid repellent fabrics by treating with chitosan and fluoropolymers. The dual finished fabric has been found of having low antimicrobial and air permeability values. On the other hand Bagherzadeh *et al*. [57] used cetyltrimethylammonium bromide (CTAB) and fluoroalkyl acrylate copolymer for developing a dual finished fabric. The water repellency was found to be under satisfactory level but the moisture vapour permeability was found to be very poor. Literature review reveals that a dual finished fabric with good breathability is a tough and tedious work. Therefore, the protective surgical gowns should have antimicrobial and liquid/water repellency properties without hampering the air permeability. Researchers have also explored various combinations including antimicrobial QACs with liquid repellent fluoropolymers [58] and silver nanoparticles with silicon based liquid repellents [59]. These combined finishes have shown promising results in reducing microbial growth and liquid penetration. However, there are still challenges to be addressed including durability of the finishes after repeated washing and wear, potential toxicity of antimicrobial agents and balance between antimicrobial efficacy and liquid repellency. Overall, the development of antimicrobial and liquid/blood repellent finishes on cotton fabric for hospital usage is an active area of research, with ongoing efforts to improve efficacy, durability and safety.

**CONCLUSION:** Antimicrobial and liquid/blood repellent finishes on cotton fabric are crucial for hospital applications, providing a critical layer of protection against healthcare-associated infections (HAIs) and cross-contamination. The development of combined finishes has shown promising results, offering enhanced protection and improved durability. However, challenges remain, including the need for balanced efficacy, durability and safety.

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**CONFLICTS OF INTEREST:** Nil

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