II. REVIEW OF LITERATURE

The review of literature pertaining to the study on “Fabrication and Enhancement of Plasma Treated Cotton, Tencel Cotton and Modal Cotton with Anti-bacterial and Mosquito Repellent Finish”

This chapter provides general information on the type of fibers used in this study such as cotton, tencel and modal. Additionally, discussions on the earlier literature available in the public domain have been provided. A succinct literature review on the principles of plasma application in textiles and its effects has been included. As this research work focuses on anti-bacterial and mosquito repellent finishes using natural material such as Guava (*Pisidium guajava*), Prickly Chaff Flower (*Achyranthes aspera*), keelanelli (*Phyllanthus niruri*) and Vetiver (*Vetiveria zizanioides*), a thorough literature review on the characteristics of different natural finishes used has been provided in this chapter.

2.1 Properties of Yarn

Table – I shows the physical properties (100% cotton, 100% Tencel and 100% modal).

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Particulars</th>
<th>Cotton</th>
<th>Tencel</th>
<th>Modal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Density (g / cm$^3$)</td>
<td>1.55</td>
<td>1.7</td>
<td>1.53</td>
</tr>
<tr>
<td>2.</td>
<td>Tenacity (cN tex$^{-1}$)</td>
<td>23 – 25</td>
<td>42 – 44</td>
<td>40 – 50</td>
</tr>
<tr>
<td>3.</td>
<td>Elongation (%)</td>
<td>7 – 9</td>
<td>14 – 16</td>
<td>5 – 10</td>
</tr>
<tr>
<td>4.</td>
<td>Wet tenacity (cN tex$^{-1}$)</td>
<td>27 – 31</td>
<td>37 – 41</td>
<td>35</td>
</tr>
<tr>
<td>5.</td>
<td>Wet elongation (%)</td>
<td>12 – 14</td>
<td>16 – 18</td>
<td>7 – 12</td>
</tr>
<tr>
<td>S.No.</td>
<td>Physical properties</td>
<td>Methods and instrument</td>
<td>100% Cotton</td>
<td>100% Tencel</td>
</tr>
<tr>
<td>-------</td>
<td>---------------------</td>
<td>------------------------</td>
<td>-------------</td>
<td>-------------</td>
</tr>
<tr>
<td></td>
<td>Count CV%</td>
<td>Electronic Lea CSP Tester</td>
<td>2.95</td>
<td>1.0</td>
</tr>
<tr>
<td>2.</td>
<td>Unevenness (U%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>U%</td>
<td>ASTM-D-1425-96 Uster Evenness Tester 4</td>
<td>16.4</td>
<td>9.44</td>
</tr>
<tr>
<td></td>
<td>Imperfection /1000 M : TC / LAB/TM-01</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Thin places (-50%)</td>
<td>ASTM-D-1425-96 Uster Evenness Tester 4</td>
<td>168</td>
<td>Nil</td>
</tr>
<tr>
<td></td>
<td>Thick places (+50%)</td>
<td></td>
<td>1036</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Neps / Km (+260%)</td>
<td></td>
<td>2210</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Total Imperfections / 1000 M</td>
<td></td>
<td>3414</td>
<td>79</td>
</tr>
<tr>
<td>3.</td>
<td>Hairiness Index</td>
<td>Uster Standard Method</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Average Hairiness</td>
<td>Uster Tester – 4</td>
<td>6.03</td>
<td>5.29</td>
</tr>
<tr>
<td></td>
<td>Standard Deviation of Hairiness</td>
<td></td>
<td>1.71</td>
<td>1.30</td>
</tr>
<tr>
<td>4.</td>
<td>Strength and Elongation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single Thread Strength (grams) Force</td>
<td>Uster Standard Method ISI 670-91 Uster Tensorapid 3</td>
<td>208.6</td>
<td>315.0</td>
</tr>
<tr>
<td></td>
<td>CV% of Single thread strength</td>
<td></td>
<td>8.9</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td>Average % Elongation at break</td>
<td></td>
<td>5.67</td>
<td>7.34</td>
</tr>
<tr>
<td></td>
<td>CV% elongation</td>
<td></td>
<td>8.52</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>Tenacity (RKM)</td>
<td></td>
<td>13.1</td>
<td>21.4</td>
</tr>
</tbody>
</table>

### TABLE – I

**PHYSICAL PROPERTIES (100% COTTON, 100% TENCEL AND 100% MODAL)**

#### 2.2 Type of Fabric

The type of fabrics is used in the study is the simple plain woven. Plain weave is the simplest form of weave and its construction and cost of manufacture makes it well suited for developing commodity clothing.
2.3 Plain Weave

The construction suits it to cheap fabrics. It has the shortest repeat and the highest interlacing of any common weave (Mahadevan, 2005).

2.4 Functional Finishes

Special finishes are a combination of chemical and mechanical finishes. These finishes are mainly applied or performed on textiles to improve the properties of fabric / fibres as per end use (Rekha and Poornima, 2005). Goyal and Deshpande (2006) highlights of the finishes that in addition to aesthetic values in terms of appearance handle and feel additional technological properties as per the requirement of the consumer are called specialty finishes. Some of the special finishes that are gaining popularity are the following: wrinkle resistant finish, anti-microbial finish and flame retardant finish.

Functional finishes represent the next generation of finishing industry, which make textile materials act by themselves. This means that they may keep us warm in cold environments or cool in hot environments are providing us with considerable convenience, support and even fun in our normal day-to-day activities. In functional finishes the fabric is imparted certain characteristics that give specific end requirements. Durable press, fire retardant, water repellent, waterproof, boosted and thermal conductivity are some of the finishes that contribute to the fabric additional, special functional features (Sampath, 2003).

Functional finishes like wrinkle resistant, mosquito repellent, anti-bacterial and UV protection. Different types of finishes have been introduced in a variety of combinations with other finishes in a variety of substrates ranging from garments, to home textiles to work wear (Anil, 2007). According to Gautam et al. (2007) that technical performance and functional properties means more than their aesthetic or decorative attributes. On the basis of the end-users, many new terms have emerged including ‘function
textiles’ and ‘specialty textiles’. Speciality textiles use some specific technologies in addition to the conventional technologies so that the product would add value to a specific attribute (Gupta, 2007). Functional finishing is the process of finishing operation on doing fabric with a particular appearance, surface texture (or) behavior characteristics and chemical processing of fabrics made its presence both nationally and internationally (Parmer, 2007). Some of functional finishes are anti-microbial, water repellent, stain repellent and fire proof. The anti-microbial finish protects wearer of the textile product against bacteria, fungi, yeasts, viruses and other microorganisms (Jasuja, 2004).

2.5 Plasma Application

Plasma was identified by Sir William Crookes as early as in 1879; however, “plasma” was applied to ionized gas only in 1929 by Irving Langmuir. Plasma is considered as the fourth state of matter, after solid, liquid and water (Saravanan, 2007). Plasma distinguished itself from the other states of matter because it contains charged particles (Buyle, 2009). Plasma is defined as a partially or wholly ionized gas with an equal number of positively and negatively charged particles. The plasma technology has been widely investigated in areas like semiconductors, tool making, general plastics and film industries.

Plasma as a very reactive material can be used to modify the surface of a certain substrate depositing chemical materials to impart some desired properties and removing substances which are previously deposited on the substrate (Sujatha, 2010).

The technology can enhance the function of the textile and garment such as crease resistant, UV protection and offer hydrophillic and hydrophobic properties, including water – oil or stain-resistant with excellent hand feel, rapid drying and breathability features (Gorjane and Bakosek, 2010). Plasma finishing is a dry process, environmentally friendly, safe and cost effective.
Plasma technology can be applied to a wide range of materials such as soft products like textiles and hard products like plastics.

Plasma technology is a surface sensitive method that allows selective modification in the NM range. By introducing energy into a gas, quasi-neutral plasma can be generated consisting of neutral particles, electrically charged particles and highly reactive radicals. If a textile to be functioned is placed in a reaction chamber with any gas and the plasma is then ignited, the generated particles interact with the surface of the textile. In this way the surface is specifically structured, chemically functionalized or even coated with a NM thin film depending on the type of gas and control of the process (Desai, 2008).

The plasma atmosphere consists of free electrons, radicals, ions, Ultra Violet (UV) radiation and a lot of different excited particles independence of the gas used. Different reactive species in the plasma chamber react with the substrate surface. Cleaning, modification or coating occurs depends on the used parameter (Vohrer, 2009). Plasma is a Greek word meaning “collective”. It can exist over an extremely wide range of temperature and pressure. Some scientist has dubbed plasma as “the fourth state of matter” because the plasma is neither gas nor liquid. Plasma can be defined as a partially or wholly ionized gas with a roughly equal number of positive and negative charged particles, in excites states, radicals, met stables and vacuum ultra violet radiations (Kakad, 2006).

Plasma is quite new technology is not a single technology. It can be thought of “tool box” of technologies that provide surface solutions to a wide range of material and application. The plasma modifies the surface of the fabric by the bombardment with high energy electrons and ions (Karthik et al., 2006 and Murugesh and Shanker, 2005).

Plasma modification of textiles saves large quantities of water, chemicals and electrical energy which is made possible since the plasma
process does not produce large volume of waste or toxic byproducts (Desai, 2008). Modification of textile surface by plasma treatment offers a lot of benefits and overcomes the drawback of the classical wet chemical finished (Kale, 2010).

2.5.1 Effect of Plasma on Fibres and Polymers

Mullani and Wasif (2011) states that when a textile material is subjected to plasma treatments undergo major chemical and physical transformations including (i) chemical changes in surface layers, (ii) changes in surface layer structure and (iii) changes in physical properties of surface layers. Plasma creates high density of free radicals by disassociating molecule processes. This causes the disruption of the chemical bonds in the fibre polymer surface which results in the new chemical species. Both the surface chemistry and surface topography are affected and the specific surface area of the fibres is significantly increased. Plasma treatment on fibres and polymers surfaces results in the formation of new functional groups which affect fabric irritability as well as facilitate growth polymerization which in turn affect liquid repellents of treated textiles.

2.5.2 Types of Plasma

The plasma of gaseous matters used in the plasma processes appears to vary depending upon the effects targeted. Reactive gases, inert gases, water vapor and combination of these are used on all types of textile material depending upon the applications. There are two types of plasma are thermal plasma / high temperature plasma and cold plasma / low temperature / non-equilibrium plasma.

Gas plasma treatments of materials alter their surface character without affecting their bulk properties. The depth of the surface treatment is only a few nanometers. The surface of the material is roughened and surface chemical properties may also be changed. So, for textiles, gas plasma treatment offers an alternative method of surface treatment to the coating
technologies conventionally applied. The idea of treating materials with gas plasma is by no means new (gas plasmas were introduced in the 1960s!), but it is only recently that it has become possible to treat textiles in this way on a commercial scale.

2.5.3 Principles of Plasma

Plasma is often called the “fourth state of matter”, the other three being solid, liquid and gas (Buyle, 2009). The physical definition of “plasma” is an ionized gas with an essentially equal density of positive and negative charges. It can exist over an extremely wide range of temperature and pressure.

2.5.4 Classification and Application of Plasma

Plasma has been broadly classified into low pressure plasma and atmospheric pressure plasma. Atmospheric pressure plasma is further classified as Corona Discharge (CD), Dielectric Barrier Discharge (DBD) and Atmospheric Pressure Glow Discharge (APGD) (Muguntarajan et al., 2009).

There are different methodologies to include the ionization of plasma gas for textile treatment. A glow discharge method which plasma gas is produced at reduced pressure and assures the highest possible uniformity and flexibility of any plasma treatment. It is formed by applying a direct current, microwave, low frequency (50 Hz) voltage over a pair or a series of electrodes. Alternatively, a vacuum glow discharge can be made by using microwave (GHz) power supply (Sujatha, 2010).

A Corona Discharge method which plasma gas is produced at atmospheric pressure by applying a low frequency pressure pulsed high voltage over an electrode pair (Ho Kai-Chiu, 2007). The dielectric barrier discharge method is in which plasma gas is produced by applying a pulsed voltage over an electrode pair of which at least one is covered by a dielectric material. Dielectric Barrier Discharge (DBD) is also called silent and atmospheric pressure glow discharges (Samanta, 2006).
Low pressure plasma is one of the oldest types of cold plasma. It is produced in a vacuum vessel having reduced pressure in the range of $10^{-2}$ to $10^{-3}$ mbar created by a vacuum pump (Muguntharajan, 2009). The gas to be ionized is supplied into the vacuum vessel, between two electrodes connected to a high voltage (0.4 – 0.8 KV) and high frequency electro-magnetic field (40 KHz – 2.45 GHz) and gets ionized. A specific characteristic of plasma is the visible glow discharge with colors ranging from blue-white to dark purple depending on the type of gas. The highly reactive particles react with the surface of the substrate. The advantage of this plasma is that it is a well controlled and reproducible technique. The low pressure plasma technology is such an alternative where on a dry environmental friendly and cost-efficient way the surface is modified on a microscopic level without manual operations or the use of chemical products (Samanta, 2006).

### 2.5.5 Characteristics of Plasma Application

Plasma technology envelops and cleans the fibres of woven and nonwoven to significantly enhance their wettability, printability, dyeability and fibre capillarity. Significant improvement in the ink adhesion dyeing depth and color fastness to textile webs, yarns and filaments have been achieved, along with the pre-sterilization of various medical grade textiles.

The percentage of initially present gaseous atoms or molecules that have been decomposed into charge carriers, i.e., degree of ionization, is one of the important factors in plasma technology in deciding the efficiency of the process. The radicals generated in the plasma region must be given the opportunity to move to the reaction place on the textile fibre surface. The path of radicals between the location of generation and reaction is limited by the distance between single fibres and a gas particle, i.e., mean distance between gas particles (Kale, 2010).

The effectiveness of a plasma treatment is governed by a variety of factors: the composition of the gas, the type of textile, the pressure within the
plasma chamber, the frequency and power of the electrical supply, and the
temperature and duration of the treatment. The treatment process is hence
highly complex; even so, several effects can be readily highlighted despite
these complexities.

Examples of the types of gas plasma applied and their effects are
given in the Table – II.

<table>
<thead>
<tr>
<th>Gas Plasma</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argon</td>
<td>Increased surface roughness</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Modification of surface chemical groups</td>
</tr>
<tr>
<td></td>
<td>Better wetting</td>
</tr>
<tr>
<td>Fluorocarbons</td>
<td>Polymerization</td>
</tr>
<tr>
<td></td>
<td>Improved water repellency</td>
</tr>
<tr>
<td>Ammonia, carbon dioxide</td>
<td>Modification of surface chemical groups</td>
</tr>
</tbody>
</table>

2.5.6 Advantages of Plasma Application

The plasma treatment of polymeric material has a lot of benefits
compared with classical wet chemistry finishing. It is applicable to all
substrates suitable for vacuum processes, i.e., almost free choice of substrate
materials. The consumption of chemicals is very low due to the physical
process (Mullani and Wasif, 2011). The process is performed in a dry, closed
system and excels in high reliability and safety, environmentally friendly and it
increases abrasion resistance, dyeing speed (Vohrer, 2009).

On polymers which are unable or very difficult to modify with wet
chemicals the surface properties can also easily be changed. Plasma
treatment changes polymers to give them particular properties hollow fibre's
surface aromatic fibres with the consequent connection of functional group
and makes fabrics anti-bacterial linen fibres crease-resisting and it reduces
the loss of weight during washing, it replaces those proceedings that use chlorine, it sterilizes material using reduced content of chemical products (Shishoo, 2007).

Plasma treatment gives low felting, enhancing dimensional stability and dirt repellent, hydrophillic to polypropylene bonded fibre fabrics, liquid repellent capacity to awning materials, oil repellent capacity, functionality to polyester fibres to better their dyeing. It shortens times of dye fixation, gives better solidity of printing pigments in polyester.

Moreover, it is applicable for different kinds of textile treatment to generate more novel products to satisfy customer’s need and requirements. It is also a simple process that could be easily automated and maintain good parameter control (Sudha et al., 2006). It is applicable to most of textile material for surface treatment. Optimization of surface properties of textile materials without any alteration of the inherent properties without any expenses for effluent treatment. It is a green process without generation of chemicals, solvents or harmful substances. The consumption of chemicals is very low due to the physical process. It is applied for different kinds of textile treatment to generate more novel products to satisfy customer’s need and requirement (Shishoo, 2007).

It requires no water for treatment; it is done in the gas phase only. Only a small amount of chemicals is needed. There is virtually no waste production. The treatment is confined to fibre surface only lower consumption is low. Process time is short coating can occur with a fully constructed end product (Sparavigna and Wolf, 2005). The low temperature avoids sample destruction / deterioration. It's dry and eco-friendly nature. A closed process excels in high reliability and safety. It facilities quicker response to market as an overall fabric preparation time is reduced. Fabric drape remains unaltered. Water used for cooling can be recycled. It helps in achieving desired surface polarities; enhance in dyeing rate (Pal and Kaur, 2006).
2.6 Microorganisms

As plasma finishing is used as a pretreatment to chemical finishing treatment such as anti-bacterial and mosquito repellent the following section of the thesis is focus on topics related to microorganisms and countering those using herbal treatments. Additionally, the chapter also discusses relevant information on mosquito repellent finish on textiles.

Microbes are minute organism that is so small under microscopic. Microorganisms such as bacteria, fungi, mildew, molds and yeasts are found everywhere in nature, even in hostile environments. The human skin is usually crowded with innumerable microorganism. A suitable temperature, moisture, dust and receptive surface provide perfect conditions for their growth (Rhodes et al., 2013).

Bacteria are unicellular organisms which can grow very fast under warm and moist conditions. Bacteria feed on a variety of food available from fabric and skin. They give out waste products which results odour and stain (Srikanth, 2010). Bacteria are produced by cell division, which can occur every 20 minutes (Rakesh, 2005). In optimum conditions turning, a single bacterium into 8 million bacteria in as little as 8 hours. Further, subdivisions in the bacteria family are gram positive, gram negative, spore bearing or non spore bearing type. Any specific type of bacteria is pathogenic and cause cross infection. Fungi, moulds or mildew are complex organisms with slow growth rate. They stain the fabric and deteriorate the performance properties of the fabrics.

Algae (singular alga) are a large group of diverse organisms, and eukaryotes, which means that the DNA in their cells is contained within a nucleus enclosed by a membrane. They can produce their food by photosynthesis. Hence, they need continuous sources of water and sunlight to grow and develop darker stains on the fabrics. Dust mites are eight legged creatures that spoil household textiles such as blankets, bed linen, pillows,
mattresses and carpets. They might feed on human skin cells and liberated waste products can cause allergic reactions and respiratory disorders. With the disturbance of the more or less balanced inter relationship between the organisms and host resistance, individual forms of microorganisms may overgrow and induce disease in the host’s tissues (Rahul, 2003).

Bacteria are produced by cell division, which can occur every 20 minutes in optimum conditions turning, a single bacterium into 8 million bacteria in as little as 8 hours. They give lot of waste products, which can result in odour emitted and staining (Deepti and Ankur, 2007). The human skin supports to growth of bacteria because of its metabolic side product, such as acidic, basic perspiration and urine. During the normal course of living our skin comes in contact with the soil and hence clothing and textile serve as carriers and also good media for pathogenic odor generating bacteria, molds and fungi. They include a variety of microorganisms like bacteria, fungi, algae and viruses (Thilagavathi et al., 2007).

Microbes require certain conditions to grow including dirt, perspiration, warm environment moisture (such as humidity or spills) and a receiving surface like skin or fabric. Microbes adapt to different micro environmental conditions like pH, temperature and pressure even at extreme variance because of their wide biochemical versatility. Microbes are capable of developing tolerance to contaminants that induce a toxic effect on their vital functions (Rajendran, 2006).

Microbes like bacteria, virus, fungi and yeast are present almost everywhere, whereas human beings have an immune system, to protect against the accumulation of microorganisms, materials such as textiles can easily be coincide by high numbers of microbes or even decomposed by them. Textiles are carriers of microorganisms such as pathogenic bacteria, odor generating bacteria, mold and fungi. Additionally, the environmental conditions on textiles are favorable and thus support the bacteria growth.
Indeed, microorganisms are invisible and extremely adaptable (Kathirvelu et al., 2009).

The dust mite fed on human skin cells and liberated waste products can cause allergic reactions. Microbial infestation poses danger to both living and non-living matters. Hence there is a necessity and expectation for a wide range of textile products finished with anti-microbial properties (Gopalakrishnan, 2006). Bacteria are simple unicellular organisms. They thrive on moisture and warmth of the body. To classify bacteria on the basis of their morphology is extremely difficult. Generally, bacteria are very small and have simple shapes. It can be divided into two groups: gram positive and gram negative (Srikanth, 2010).

2.6.1 Effect of Microbes on Textiles and Humans

Although microbes can be useful in many ways, for example, in brewing, baking and biotechnology, they can also be harmful to both textiles and humans. Different substances added to textiles such as size and modifiers, anti-stats, thickness, lubricants and dirt as well as grease, sweat and dead skin from the human body provide a great source of nourishment for microorganisms (Tanveer, 2010).

The ideal growth conditions for microorganisms exist in the human being and for this reason clothing, textiles are very prone to infestation by microbes. This applies to natural fibres as well as synthetic ones and not only to clothing, but also home textiles such as bed linen, towels and carpets. Rapid increase in allergies is often provoked by microorganisms such as mold fungi. In addition to provoking allergies such as microorganisms can also directly cause diseases (Shroff, 2001). One of the most susceptible garments to microbial attack is next to the skin garments which remain close to skin secretions such as perspiration and secretions from axillallary and pelvic regions. The contaminated next to the skin garments can cause infections like furuncles and boils. This problem cannot be eliminated by even most frequent
washings with the exception of washing at boiling temperature. Microorganisms are most dangerous creating harm to our lifestyle in different ways. So to take environment healthy, hygienic and fresh it becomes very important to have the control over the growth of the microorganism and for these the garments should be treated with some specialty chemicals which can restrict the growth of microorganisms (Tarafder, 2011).

### 2.6.2 Effect of Mosquitoes

Mosquito is a common insect in the family Culicidae. Mosquitoes resemble crane flies and Chironomid flies, with which they are sometimes confused by the casual observer. There are about 3,500 species of mosquitoes found throughout the world. The mosquito-borne diseases are mostly of the zoonotic variety. “Zoonotic” means a disease can be transmitted across multiple species (Strickman et al., 2009). Mosquitoes are among the most common and widely distributed insects (Kumaravel and Kantha, 2009).

Few genera of mosquitoes are major vectors of human diseases such as malaria, filariasis and viral diseases like Japanese encephalitis, dengue, dengue hemorrhagic fever, yellow fever, chikengunya etc. (Raghavendra et al., 2008). Mosquito control is becoming increasingly difficult because of the development of resistance in vectors of conventional insecticides (Kalyanasundaram et al., 2003). The recently introduced West Nile fever is caused by a virus and transmitted by a wide variety of mosquitoes, primarily species in the genus Culex, that have fed on infected birds.

Control of mosquitoes has been principally provided by the use of synthetic insecticides. Some of the plant species may possess substances with a wide range of activities like anti-feedant, anti-oviposition, repellent and growth-regulating activity (Kumar, 2008).
2.7 Anti-microbial Finish

The term “anti-microbial” refers to a broad range of technologies that can provide varying degrees of protection or control of a textile product against the attack of microorganisms such as bacteria, mildew, etc. and the problems of deterioration, staining, odors and health concerns, that they cause (Achwal, 2003). According to Rahbaran (2002) the term anti-microbial finish indicates limiting the growth of bacterial colonies and their extinction. Anti-microbial finishes work by controlling the multiplication of microorganisms and thus suppressing the generation of unpleasant odors.

Anti-microbial finish is a recent innovation in finishes. The consumers are now increasingly aware of the hygienic lifestyle and there is a necessity and expectation for a wide range of textile products finished with anti-microbial properties. Anti-bacterial agents destroy or inhibit the growth of microorganism. Anti-microbial finishes control, destroy or suppress the growth of microorganisms and their negative effects of odor, staining and deterioration. Anti-microbial agents migrate and chemically enter or react with the microorganism. Anti-microbial finishes acts as a poison for them. There are different types anti-microbial finishes based on chemical and natural sources (Thilagavathi et al., 2007).

An anti-bacterial is one that has been chemically treated to kill, or suppress the growth of harmful microorganisms. The demand for anti-bacterial finishes in the textile industry continues to rise as new products and applications are introduced. Consumers identify anti-bacterial textiles with cleanliness and protection against microorganisms and have come to expect it in new textile products (Sathianarayanan et al., 2010).

The increasing consumer demand for hygienic products has dramatically increased anti-microbial substances use in textiles. Anti-microbial textile products vary in their effectiveness and durability depending on the type of fabric, the agent, and the finishing method used (Pelin et al., 2010).
According to Shanmugasundaram (2006) negative effect on the vitality of the microorganisms is generally referred to as an anti-microbial. Anti-microbials are used to control bacteria, fungi, mold, mildew and algae. Their control reduces or eliminates the problems of deterioration, staining, odors and the health concerns that they cause (Joshi, 2010).

Anti-bacterial agents can be integrated into the fibres directly or can be applied to textile surfaces by a conventional textile finishing process (Ureyen et al., 2010). The use of natural products such as Chitosan and natural dyes for anti-microbial finishing of textile material has been widely reported. Other natural herbal products such as Aloe vera, tea tree oil, eucalyptus oil and tulsi leaf extracts can also be used for this purpose. There is a vast source of medicinal plants with active anti-microbial ingredients (Joshi et al., 2009).

Textile products which are made of natural, synthetic or blended fibres are sensitive to contamination by and growth of pathogenic microorganisms. Anti-microbial finish is one of the special finishes offered to the textiles where the scope of the growth of bacteria is high and the safety is paramount. Anti-microbial treatment on the undergarments controls the growth of the microbes on it which will in turn control the above effects. They maintain hygiene and freshness and stop bad odor (Tarafder, 2011).

The anti-bacterial agents can be applied to the textile substrates by exhaust, pad dry cure coating, spray and foam techniques. The substances can also be applied by directly adding into the fibre spinning doe. It is claimed that the commercial agents can be applied online during the dyeing and finishing operations (Rajesh and Chakrabarth, 2010). The anti-microbial textiles can be classified into two categories namely passive and active based on their activity against microorganisms. Passive materials do not contain any active substances but their surface structure produces a negative effect on the living conditions of microorganisms. Materials containing active anti-
microbial substances act upon either in or on the cell (Ljiljana and Peter, 2010).

The anti-bacterial activity of the bio-transformed compounds was examined by agar diffusion methods and measured in terms of the diameter of inhibition zone produced around the cells. The minimum inhibitory concentration was calculated as the last concentration of cyanohydrins which inhibited the growth of microorganisms (Khobragade et al., 2005).

2.7.1 Types of Anti-bacterial Finish

The anti-microbials are of two types, namely leaching and non-leaching type. The leaching type anti-microbial is not chemically bonded with the fabrics and can be removed from contact with moisture. The mechanism involved in this type is to poison the microorganisms. There include their negative effects since, they can contact the skin and affect the normal skin. Bacteria cross the skin barrier and cause rashes and other skin irritations. It is effective for single use and loses its effectiveness on subsequent washing (Shukla and Sundar, 2008).

The non-leaching types of anti-microbial agents are chemically bound to the surface of the textile materials and thus do not lose their effectiveness by becoming depleted nor they cause harm to anything other than microorganisms. These agents do not lose their effectiveness even on repeated laundering (Chakraborty et al., 2010).

2.7.2 Properties of Anti-bacterial Finish

Anti-bacterial finish maintains hygiene and freshness and stops bad odor from the surface of the fabric. Controls or eliminates microbial staining and improves the life of the articles wherever it is applied. Improves hand of most of the fabric, eliminates the chances of disease transmission and is effective on any substrate like cellulose, synthetics as well as their blends and any surface other than textiles (Ganesan et al., 2008). Anti-bacterial finishes
add value to textiles and protect the wearer or user of a textile against bacteria, yeast. Fungi and other related microorganisms for aesthetic, hygienic or medical purposes. It protect the textile against bio-deterioration caused by mould, mildew and rot producing fungi and protect the textile from insect and other pests for preservation of the fibre / or protection if persons wearing clothing from insects and pests.

Anti-bacterial finish properties are to control the infestation by the microbes and to arrest metabolism in microbes and to protect textiles from staining discoloration and quality deterioration and prevents the odor formation (Ramachandran et al., 2004). This finish should prevent the transfer and spread of disease promotes (Achwal et al., 2003).

Anti-bacterial finish should not be toxic to the human body and should be compatible with other finishes (Parthiban, 2006). This finish maintains hygiene and freshness and it control or eliminates microbial staining to stop skin irritation (Menezes, 2004). It eliminates the chances of disease transformation and it is effective on any substance like cellulose, synthetics as well as their blends and any surface other than textiles (Srivastava, 2010).

2.7.3 Requirements of Anti-bacterial Finish

Textile material in particular, the garments are more susceptible to wear and tear. It is important to take into account the impact of stress, strain, thermal and mechanical effects on the finished substrates. According to Vishnu and Bagya (2010) finishes should preferably be compatible with textile chemical processes such as dyeing is cost effective and not produce harmful substances to the manufacturer and the environment. It should not kill the resident flora of non pathogenic bacteria on the skin of the wearer. Finishing should have acceptable moisture transport properties and should be easy to apply (Gaurav, 2005). The finish should be resistant to body fluids and to disinfection / sterilization.
The following requirements need to be satisfied to obtain maximum benefits out of the finish.

- Durability to washing, dry-cleaning and hot pressing.
- Selective activity of undesirable microorganisms.
- Should not produce harmful effects to the manufacturer, user and the environment.
- Should comply with the statutory requirements of regulating agencies.
- Compatibility with the chemical processes.
- Resistant to body fluids and resistant to disinfection / sterilization.

The growth of microbes is rapid. The bacteria population for example, doubles every 20 to 30 minutes under ideal conditions. Therefore anti-bacterial finishes must be quick acting to be effective (Shukla and Sundar, 2008).

Anti-bacterial treatment of textile material is necessary to fulfill the following objectives.

- To avoid cross infection by pathogenic microorganisms.
- To control the infestation by microbes
- To arrest metabolism in microbes in order to reduce the formation odour
- To safeguard the textile products from staining, discoloration and quality deterioration (Gopalakrishnan, 2006).

### 2.7.4 Benefits of Anti-bacterial Finish

Anti-bacterial is an agent that works against microbes it can either inhibit their growth or reduce the undesired byproducts or kill them altogether (Rahul, 2003). The use of anti-bacterial finish improves the durability of the fabric by controlling growth of microbes, grants freshness to the fabrics and prevents skin diseases (Avernita, 2010).
According to Shroff (2001) hospital related infections are urgent health care issues. Medical textiles such as doctor’s and nurse’s uniforms, patient gowns, bed sheets, wipes and covering materials have been shown to be the carriers of drug resistant microorganisms and are potential vehicles for disease transmission in hospitals. Anti-bacterial materials which can prevent the growth of microorganisms are important not only for medical textiles, but also for use in hotels, transport industry and in biological research institutions. The use of anti-bacterial finish in undergarments helps in preventing skin related diseases and urinary tract infection. It is also desirable for baby clothing as their thin skin is permeable and highly sensitive to microbes. As the internal intake of antibiotic for the infant is not desirable, the protective action should be given via the clothing.

Besides the above application, anti-bacterial finish is also used in hygienic use apparel, sportswear, home furnishings and upholstery, industrial fabrics etc. (Anand et al., 2010). Smart consumers prefer hygienic wear because they always think, “prevention is better than cure” and this is the concept behind the anti-bacterial finish (Srikanth, 2010).

Textile fibres with built-in anti-bacterial properties will also serve the purpose alone or in blends with other fibres. Bioactive fibre is a modified form of the finish which includes chemotherapeutic in their structure, i.e., synthetic drugs of bactericidal and fungicidal qualities. These fibres are not only used in medicine and health prophylaxis applications, but also for manufacturing textile products of daily use (Menezes, 2003).

The field of application of the bioactive fibres includes sanitary materials, dressing materials, surgical threads, materials for filtration of gases and liquids, air conditioning and ventilation, constructional materials, special materials for food industry, pharmaceutical industry, footwear industry, clothing industry. Anti-bacterial finishes add value to the product for both the producer and the consumer in the following ways.
- Protection of the raw material from decay or degradation.
- Control of staining caused by microbial growth.
- Add freshness to the fabrics and the wearer.
- Elimination of smells created by microorganisms.
- Increased life period of the fabric because of control of the growth of microbes.
- Improvement in the handle of most of the fabrics.
- No irritation of the skin and no physiologic impact to human health.

2.8 Mosquito Repellent Finish

According to Benard (2000) mosquito repellents may be one of the most effective tools for protecting human from vector borne disease such as dengue hemorrhagic fever, malaria, encephalitis and filariasis as well as the nuisance caused by mosquitoes. In 1999, the conference of insect proof process was established and the method of the insect proof test and qualifying standard was decided (Nakamura and Basmatkar, 2005).

Mosquitoes cause annoyance and spread human and animal disease. The task of managing and treating large areas by spraying insecticides for controlling these pests is uneconomical and undesirable from an environmental standpoint. Application of insect repellent directly to the skin gives protection for only a few hours because it is lost by evaporation, abrasion and absorption.

The application of insect repellent to textiles is an alternative that provides long lasting protection (Shroff, 2001). Repellents are used rarely by the community to prevent mosquito bite. They contain synthetic or natural active substances of substantially varying effectiveness.

2.8.1 Types of Mosquito Repellent

Medicinal plants like Tulsi, Neem, Notchi, Lemon grass, Citronella, Keelanelli, Cinnamon, Eucalyptus, Vetiver and Turmeric are used for production of mosquito repellent. In order to avoid chemicals for repellent
activity, effects were made to find out alternate eco-friendly sources (Kumaravel and Kantha, 2009).

It is very easy to make your own natural mosquito repellent. These natural products will effectively repel mosquitoes, but they require more frequent reapplication and higher concentrations than DEET (Koren et al., 2003). Some of the natural repellent oils are citronella oil, castor oil, rosemary oil, cedar oil, peppermint oil, clove oil, geranium oil etc. The application of lemon citrus oil gave acceptable percentage biting protection against mosquito (Oshagi et al., 2003). The eucalyptus oil is acid and bitter and has a reputed astringent, thermogenic and insect repellent property. Neem seeds also possess good insecticidal properties. The neem products and the pesticides are eco-friendly and are widely used due to its wide range of action against many pests (Prasad and Reshmi, 2003). Menthoglycol is a natural insect repellent derived from lemon eucalyptus which is a natural and renewable source.

2.8.2 Requirements for Mosquito Repellent Finish

The distribution of mosquitoes has expanded from tropical regions to northern latitudes due to global warming and that leads to a spread in source of viral infection from mosquitoes. Especially, the West Nile fever virus which has infected many people around the world recently. The virus, bacteria and fungus are being arrived via wild birds imported as pets and via plane or boat in an infected mosquito. The populations of mosquito are found to be enormous day by day. The need is for finishing textile products to protect against mosquito-transmitted viral infections such as malaria, pneumonia and other diseases (Kumaravel and Kantha, 2009).

2.8.3 Chemical Repellent

According to Koren et al. (2003) over the last 50 years, synthetic repellents such as dimethylphthalate (DMP), ethyl hexanediol (EHD) and diethyl-m-toluamide (DEET) have been developed. The latter is still the most
commonly used repellent worldwide, despite concerns over its possible toxicity to pregnant women and children. N, N-diethyl phenyl acetamide (DEPA) and N, N-diethyl-m-toluamide (DEET) are non-toxic, non-irritant, cosmetically acceptable, broad spectrum insect / mosquito repellents. In recent years new formulations have been developed such as IR 3535 (ethyl 3-CN-buthyl acetyl amino propionate) which has been approved in the U.S.A. for skin application (World Health Organization, 2001).

As elaborated in the introductory section of the thesis, the use of plasma as a pretreatment to the application of herbal products is novel and there is no information available as such as in the public domain on the functional characteristics of anti-bacterial and mosquito repellent finished fabrics that have been pretreated with plasma. The thesis focuses on this aspect and presents data on plasma pretreated functional fabrics.

This chapter focused on detailed discussion on the characteristics of three different materials (cotton, modal and tencel) that are generic in nature and hence have been provided in Appendix–I. This was considered useful and important as the thesis will serve as a bibliographical reference for future researchers.

Detailed literature review on the plasma technology and its applications have been provided. Much emphasizes in this chapter has been placed on the information related to chemical treatments involving natural products to impart anti-bacterial and mosquito repellent effects on natural and regenerated fibres and its blends. To our best understanding, this thesis reports new information on the functional properties of surface modified (plasma pretreated) fabrics that have anti-bacterial and vector repellent properties, after finishing with natural products such as Guava (*Pisidium guajava*), Prickly chaff flower (*Achyranthes aspera*), Keelanelli (*Phyllanthus niruri*) and Vetiver (*Vetiveria zizanioides*).