I. INTRODUCTION

The textiles and clothing industry is one of the oldest and largest in the world, from the evidence that ancient civilizations used clothes made from natural fibres. It is a diverse and heterogeneous industry, involved in the transformation of fibre to yarn and yarn to fabrics.

Textiles have such an important bearing on our daily lives that everyone needs to know something about textiles. From earliest times, people have used textiles of various types for covering, warmth, personal adornment and even to display personal wealth. Textiles are still used for these purposes and everyone is an ultimate consumer. A textile is any type of material made from fibre or other extended linear material such as thread or yarn. The production of textiles is an ancient craft, where speed and scale of production have been altered almost beyond recognition by mass production and an introduction of modern manufacturing techniques (Thomas, 2006).

Over the years, India has emerged as a successful outsourcing center for textiles and apparel. Indian textile and apparel industry is gaining in strength with a spark of growth in investments and modernization to meet the surging worldwide demand. The capacity to manufacture fibre and yarn attracts heavy investment, continuous innovations, new product mix and strategic marketing in World-class plans.

In the recent years, India is emerging as one of the successful outsourcing center for textiles and apparels in the global market. Indian textile and apparel industry is gaining in strength with a spark of growth in investments and modernization to meet the surging worldwide demand. The capacity to manufacture different types of textile fibres, yarns, and other textile related products attract heavy investments leading for continuous innovations, production of new varieties suitable for the markets and getting strategic market in world scenario.
Now textile industries all over the world are facing challenges in the field of quality and productivity, due to the globalization. The highly competitive atmosphere and the straight ecological parameters have ensured that the prime concern of the textile processor is quality and environment. Again, the guideline of the processes thus in turn, makes it essential for innovations and changes in the processes. As a result, the research and development strategies of the textile processors will be highly focused and the challenges will face many changes in the textile industry.

The textile industry is currently moving away from being a conventional craft to developing high-tech and fashion products. This necessitates the need for the utilization of sustainable and modern manufacturing methods.

Eco-friendly products are highly beneficial to our health as also to the environment. The quality of our lives can be greatly improved with the use of these green products that are made from natural raw material. The manufacturing of these products causes minimal harm to the environment. Textiles were first developed as a means for carrying food, as mats in shelters and later used as clothing. Cotton is the most popular amongst the fibres admired by the consumer all over the world for its fascinating feel, comfort and versatility (Malikprem, 2007).

In a country like India, with extremes of temperature and humidity garments made from natural fibres in cotton or blends of man-made and natural fibres are certainly preferred purely for the reason of environment and health (Sangwan et al., 2006). Cotton fabrics are very popular in a tropical country like India (Anita, 2011).

In this research, plasma treatment has been used as a surface enhancement method to bond antimicrobial finishes on the cotton surface. As plasma treatment creates surface charges it helps in the surface attachment of the chemical finishes applied. The charges and ions created
due to surface treatments enhances the overall treatment efficacy and the durability of the treatment process.

Fibres are abundantly available in nature. Since time immemorial, human beings have been increasingly dependent on fibres and fibrous material for shelter, coverage, packaging, protection and warmth. In the prehistoric time, for protection and warmthness man depend on animal skin and fur. Frings (2002) describe the looked around the world for practically elegant and comfortable fibre, which man found the short staple length and long filament fibres from plants and animals. Using his ingenuity, he developed methods of each of these fibre could be twisted or spun together to form a thread or yarn. The thread or yarn was then put through mechanical processing such as weaving or interlacing for obtaining flexible, warm and highly comfortable, stable, durable and usable material known as cloth.

Cellulose is one of the main constituent of plants, trees and grasses. Cotton cellulose is the purest form which consists of 90% cellulose. Cellulose is widely used for making eco-friendly innovations at every point in the value chain. Regenerated cellulosic fibre is a general term for manufactured fibre or yarn produced chemically from cellulose or with a cellulose base and for strand, or fabrics made from cellulose content. It is composed of pure cellulose, the substance of which the cell walls of such woody plants or trees and cotton are largely comprised. These fibres are identified as regenerated cellulose fibres. The raw materials extruded are cellulose or cellulose base.

Natural textile fibres are more susceptible to microbial attack than synthetic fibre. At the same time, human skin supports growth of bacteria, because of its metabolic side products such as acidic and basic perspirations and urine, although it is possible that the most important barrier to prevent microorganisms entering the body. Our skin is too infested with countless number of microorganisms. It can be found almost everywhere in the environment. NASA researchers have found microorganisms even at a height of 32 km and to a depth of 11 km from the sea. These microbes require
certain conditions to grow including dirt, fibre or perspiration, warm environment, moisture (such as humidity or spills) and a receptive surface like skin or fabric (Menezers and Choudhary, 2007). The identification and development of an anti-microbial agent have been proven to be a lengthy and multifaceted process requiring the interaction of many scientific disciplines.

Modal is a bio-based fibre made by spinning reconstituted cellulose from Beech wood pulp. It is biodegradable and is about 50% more hygroscopic, or water absorbent, per unit volume than cotton. It is designed to dye just like cotton and it has good fastness towards washing in warm water. Modal is essentially a variety of rayon (Rastogi, 2009). Modal fibres were initially developed in the year 1930s for industrial uses in tyres, conveyor belts and hose pipes.

Modal is currently called the new wonder fibre. Modal has been providing a feeling like “skin to skin”. Modal fabric has strength, softness, good drape, wear resistant and comfortable for wearing. Modal fabric has good moisture regain and air permeability which is often considered better than cotton fabric. Modal fabric has leveled up surface, fine, smooth and velvet which have the effect of natural silk. The garment maintains antique properties and has relatively ease care. Modal fibre contains an anti-bacterial agent that exhibits low solubility in water alkalies and acids (Mahapatra, 2007).

Tencel is a natural, man-made fibre produced in an environmentally – friendly process from wood pulp. Tencel, made from wood pulp cellulose offers a unique combination of the most desirable properties of man-made and natural fibre soft like silk, strong like polyester, cool as linen, warm as wool and as absorbent as cotton (Chellamani et al., 2006). It is manufactured using highly eco-friendly process with minimal environmental impact and excellent ecological credential with enhanced physical properties such as strength, absorbency and stretches more than cotton. It resists wrinkling, machine wash and quick dry (Achwal, 2000).
It is Lenzing fibre brand name for Lyocell. Tencel heralds the beginning of a new age in fibre technology (Sahu, 2006). It is fibrillar in structure and resembles cotton even more closely than modal fibre in its behavior under stress and capacity for absorbing liquid water. It can contribute to the strength of the blended yarn even to low blend levels. An interesting feature of tencel is that the conversion of fibre strength to yarn strength is considerably higher than for other cellulosic fibre types. It improves the performance of blends with cotton by enhancing strength, luster, yarn regularity, spinning and wear performance (Shipla et al., 2004).

It is yarn dyed and absorbs colour much better than most other cellular fibres. It drapes well luxurious, wrinkle less, soft, absorbent, much more resistant to ripping, breathable and very comfortable to wear. The dermatological study, wearing tencel significantly improves comfort and promotes a feeling of well being (Diepgen and Schuster, 2006).

The yarn is made into fabric through different manufacturing processes such as weaving, knitting and non-wovens. In this weaving is more popular and than others.

Weaving is one of the processes of manufacturing fabric. It consists of two series of thread of the warp and weft directions interlaced at right angles to each other. The warp threads run the length of the fabric and the weft thread run across the width of the fabric (Vidyasagar, 2005). Fabrics are classified as to weave or structure according to the manner in which warp and weft cross each other. The three fundamental weaves of the plain, twill and satin weave (Thomas, 2006).

The woven fabric as soon as it comes out of the loom consisted of more impurities and natural colour, because of this the finishing and dyeing won’t get uniform on the fabric. Hence, in textile industry the basic finishes are given to the fabric to remove natural impurities and natural colours.
“Bleaching for white” is carried out by treating the raw cotton successively with boiling lime-water, caustic soda and cold dilute bleaching powder solution and finally washing with cold water (Barker and Midgley, 2007). The bleaching process decolorizes the natural cotton pigments and removes any residual natural trash components not completely removed during ginning, carding or scouring (Roda, 2008). After pre-treatment the fabrics, special treatment and finishes are given to the fabric to enhance its properties.

Growing demands on the functionality of textiles as well as the environmental friendliness of the finishing processes increase the interest in physically induced techniques for surface modification and coating of textiles. Plasma is one among such treatments that is getting good attention these days for its application as a pre-treatment and finishing technique for textiles. Plasma is a gaseous state of matter that contains excited species such as ions, free electrons and large amounts of visible, Ultra-Violet (UV), Infra-Red (IR) radiation. Plasma state can be generated by electrical discharge, fusion, flames and mechanical electromagnetic radiation (Mullani and Wasif, 2011).

Plasma is an ionized gas which is a distinct fourth state of matter. In the ionized state, at least one electron is not bound to an atom or molecule converting the atom or molecule into positively charged ions. As temperature increases, molecules become more energetic and transform sequentially into solid, liquid, gas and finally plasma which justifies the title fourth state of matter (Frings, 2002).

Plasma treatment has been used to induce both surface modification and bulk property enhancement of textile material, resulting in improvements in textile products ranging from conventional fabrics to advance composite. These treatments have been shown to enhance the dyeing rates of polymers, improve color fastness and wash resistance of fabrics and change the energy of fibre and fabric (Uwe, 2009).
Eco-friendly plasma treatment can be carried out during different stages of fabric formation such as fabric preparation, dyeing and finishing of cotton, wool, silk and most of the man-made fibres. Plasma gas particles etch on the fabric surface in nano scale, to modify the functional properties of the fabric (Rena, 2010).

Plasma technology is a surface sensitive method that allows selective modification in the nanometer (nm) range. The textile that has to function is placed in a reaction chamber with any gas preferably nitrogen, oxygen or argon creating plasma, which interacts with the surface of the textiles. This technology has been introduced industry for applications such as removing sizing, adding functionality to the textile and modifying the surface properties of textiles. Plasma treatment has been predominately used as a finishing pre-treatment. Plasma makes the fabric surface reactive which helps with further chemical treatments. In this study, plasma treatment is given to fabrics which are further treated with herbal and natural products for imparting anti-bacterial and other functionalities.

Increasing global competition in textiles has created many challenges for textile researchers and industrialists. The rapid growth in technical textiles and their end-uses has generated many opportunities for the application of special finishes (Sanjay, 2013). Anti-bacterial textiles with improved functionality find a variety of applications such as health and hygiene products, especially the garments worn close to the skin (Pamela, 2009).

One of the special finishes is anti-bacterial finish. Anti-bacterial compounds are used in an eco-friendly way. The environment friendly compounds having a good degree of durability with the expected level of performance in anti-bacterial finishing. The human body generates sweat during various conditions of activity leading to sensory and thermal excitation. The bacterial contamination of sweat results into smell which can generate from various parts of the body like armpit, forearm, arm, back and forehead (Naresh et al., 2007). The natural anti-bacterial compounds are used in an
eco-friendly way. The environment friendly compounds having a good degree of durability with the expected level of performance in anti-bacterial finishing.

Bacteria are unicellular organisms which can grow very fast under warm and moist conditions. It can be divided into two groups. Gram positive and gram negative (Srikanth, 2010). Anti-bacterial textiles continue to increase the popularity as the demand for fresh smelling, skin friendly and high performance fabric. This finished fabric can minimize the transfer of microorganisms on the wearer by creating a physical barrier.

Traditional medicinal systems like the Ayurveda and Siddha, mention the use of plants in the treatments of various human ailments. India has about 45,000 plant species and among them, several thousands have been claimed to possess medicinal properties. Over the past decade, substantial progress has been made in research on the natural products for the treatment of several diseases like AIDS and cancer (Gupta and Bhaumik, 2007). Ayurvedic herbal products are creating a niche amongst the general population gradually and very rapidly. They are taking hold on the position of chemical substances which have been in major use till now. The fabrics, dyed and finished with these may get curative therapeutic properties and become a protective functional textile.

### Advantages and Disadvantages of Green Repellents

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<th>Advantages</th>
<th>Disadvantages</th>
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<td>• Generally very safe.</td>
<td>• They are “different”, so traditional use patterns may need to be updated.</td>
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<td>• Pleasant odour and feel</td>
<td>• Some have shorter residual action or protection times.</td>
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<tr>
<td>• Environmentally friendly and fully biodegradable. New uses are possible (e.g. crop protection).</td>
<td>• Costs may be higher than synthetic compounds.</td>
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<td>• Blending of mono- and sesquiterpenoids can provide an optimal blend of spatial and contact repellency.</td>
<td>• Supplies of natural products can be subjected to interruption due to crop failures. (Mustapha et al., 2014)</td>
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Repellents come under the class of insecticides. Insecticides are broadly classified into two types. They are contact insecticides and repellent insecticides. Repellents are substances that are mainly used to repel insects and pests rather than causing death. Several mosquito repellents are available today in the market of which DEET is safely used by an estimated 110 million people worldwide each year (Gopalakrishnan, 2006).

Anti-bacterial finish causes a fabric to inhibit the growth of microbes. The humid and warm environment found in textile fibre encourages the growth of the microbes. Infestation by microbes can cause cross-infection by pathogens and the development of odour where the fabric is worn next to the skin. In addition, stains and loss of fibre quality of textile substrates can also take place. With an aim to protect the skin of the wearer and the textile substrate itself.

The guava leaf extracts (*Pisidium guajava*) have *in vitro* anti-bacterial activity, mostly associated with flavanoids such as marine glycosides, quercetin and quercetin glycosides.

Prickly chaff flower (*Achyranthes aspera*) has been comprehensively indicated in Ayurveda as an anti-inflammatory agent for diseases of the urinary tract, disorders piles, indigestion, cough, asthma, anemia, jaundice and snake bite. Apamarg kosher oil is used locally in ear ache. The root powder is applied to the skin diseases for controlling skin allergies (Tirtha, 2007). It has pungent, astringent, diuretic, anti-periodic and purgative properties. It contains saponin and ecdysone. It has no toxic effect on humans (Panday, 2000). It is effective in abdominal pains and also in treating heart related disorders and increased blood pressure. Prickly chaff flower is an erect or prostrate, annual or perennial herb, often with a woody base which grows as wasteland herbs available everywhere.

Mosquito repellent textiles are one of the revolutionary ways in advance. The textile field provides the much needed features of driving away
mosquitoes, especially in the tropical areas. There are many chemicals available for achieving mosquito repellent on textiles. But most of the chemicals are banned from the World Health Organization (WHO) due to their harmfulness towards the environment. Therefore, researchers have shifted their focus towards natural mosquito repellent compiled with the requirements of WHO (Debboun et al., 2007). Mold, mildew, fungus, yeast, bacteria and virus are part of our everyday life and found everywhere in the environment (Ana et al., 2010). Natural herbs carry herbal property will be beneficial to the human body (Deepak et al., 2011). Microbial biomasses and the various extracts that can be obtained from these sources (Bruno et al., 2010).

Some of the herbal compounds obtained from plants are well known from time immemorial as anti-bacterial products. These plant products are applied directly on skin or wounds as paste or incaution either for skin care or wound healing. These natural products are abundantly available in nature and are widely distributed and the part of these plants applied to textiles. They are cheap and not processed and can be used as raw material required for applications. Apart from dyeing, these medicinal products posses distinct odour for identification and these are non irritant to skin and non toxic.

Keelanelli (Phyllanthus niruri) has the property of venereal disease, gonorrhea, can be controlled by Phyllanthus niruri. For excessive body heat, intestine ulcer, urinary tract infections, urinary stone and diabetes; it is a good remedy (Kuttan and Harikumar, 2012).

Medicinal plants like neem, keelanelli (Phyllanthus niruri) and Vetiver root (Vetiveria zizanioides) are used for production control of mosquito (Drew, 2005). The Vetiver root is easily found in nurseries, garden stores and other plant dealers and distributors. Related to lemon grass, Vetiver oil has medicinal properties. Vetiver root is a fast growing grass that is non-invasive, very deep rooting, insect and vermin proof. The aromatic roots are used in potpourri and perfumes. The essential oil from the roots is used in perfumery.
The introductory part of the thesis has been made general and brief so as to build the base for the thesis. More importantly, as it has become norm these days, the success of research is in its applicability to the industry and society. The work reported in the thesis endeavors to showcase the benefits of environmentally, friendly processes to the Indian and global textile industry based on scientific data. Therefore, the thesis briefly provides the status of Indian textile industry and the necessity for the industry to adopt modern and sustainable practices such as plasma treatment. It will be an onerous task to elaborate the state of the textile industry in India and several research endeavors an alternatives to conventional textile processing and finishing treatments. Indian textile industry is predominantly natural fibre based and hence the introductory chapter sets the stage for developing new products for the industry using green preparatory techniques such as plasma and finishing treatments using natural and herbal products.

The crux of the work carried out in this thesis research is to impart certain functionalities to cotton and its blends with green products, while using plasma as a preparatory process. Results based on such a study will be useful for the industry in developing environmentally friendly methods and products for the textile industry.

In this background, it is understood that the coupling of solvent free atmospheric plasma treatment with natural herbal materials for imparting anti-microbial characteristics to fabrics is novel and the information on this subject is limited in the public domain. In addition to that, the research work of herbal finishes in the textile fields is emerging one nowadays. Moreover, due to the environmental and sustainable aspects, such a research study and data on the microbial reduction after herbal finishing will be useful for technology transfer activities. Hence the purpose of this research project was

- To investigate the effect of oxygen plasma as a pre-treatment to the herbal finishing;
• To develop anti-bacterial and mosquito repellent textile products with selected herbs;

• To investigate the effect of different set of herbs on the mosquito repellency of textiles;

• To assess the anti-bacterial and mosquito repellent activity of finished fabrics;

• To evaluate additional properties such as physical, mechanical, absorbency and comfort properties of the treated fabrics and

• To convert the finished fabrics into consumer products and evaluate them for consumer acceptance.

Overall, the goal of the research work is to investigate the effect of environmentally beginning processes and products to impart important functionalities such as anti-bacterial characteristics to develop next generation textile products.