Introduction
1.1 Microorganisms and textiles

Microorganisms are constantly around us on our body and clothes, inhabited in the air that we breathe, in the water we use and on the soil we live. They require certain medium like moisture, temperature, dirt and receptive surfaces for their growth. The entire inner part of the human body would not function without these biological helpers. In the broad array, there are both good and bad types of microorganisms. It is extremely important to control the bad ones as they cause innumerable problems for the human body. The normal bacteria found on the skins of humans are capable of producing characteristic foul odours, especially on the foot and in the auxiliary region (Radford, 1973; Tachibana, 1976). Clothing is an important basic need of every human being as it protects one from sun, rain, air, infection and other external stimuli. However, soiled clothes besides being unpleasant, often contain large number of microbes, many of which may remain alive on fabrics for extended period of time. When the spaces on its meshes are choked with dust and dirt, cloth can no longer absorb moisture from the skin.

1.1.1 Textiles and cross infections

Textiles form a part and parcel of the human body and our skin is infested with countless number of microorganisms, most of which form part of our natural protective coating and skin flora. During the course of normal living, the human skin comes in contact with soil through which the skin and the clothings are seeded with different species of microbes. Microbes adhering to the clothing serve as one of the sources through which microorganism can enter the skin and also cause cross infection. Clothing and textile materials are not only carriers of microorganisms such as pathogenic bacteria, odour generating bacteria, moulds and fungi but also good media for the growth of the microorganisms (Anita et al., 2002). Some microorganisms, which live around the human body and multiply on textiles, have a high pathogenicity. Even if not highly pathogenic, the multiplication of microorganisms in textiles can create staining, discoloration, degradation of fibre and generation of foul odour (Hamlyn, 1990). This can be extremely critical in storage of bulk garments and finished goods.
1.1.2 Textiles as substrates for microorganisms

The microorganisms particularly bacteria can thrive on textile substrates. Natural fibres such as cotton are more susceptible than synthetics because their porous hydrophilic structure retains water, oxygen and nutrients providing a perfect environment for bacterial growth (Payne, 1997). Microorganisms multiply rapidly in textiles in the presence of heat, humidity and food source. Cotton textiles when in contact with the human body provide all requirements for microbial growth; nourishments, oxygen, water and warmth (Payne and Kudner, 1996). Textiles made from natural fibres are more susceptible to bio-deterioration in comparison to those made from synthetic man-made fibres. The products, such as starch, protein derivatives, fats and oil, used in the finishing or in the sizing bath can also promote microbial growth (Sarkar et al., 2003). As textiles provide the required medium for the growth of microbes, they can damage fabric by causing odours (such as bacteria that cause perspiration odour in apparel or moulds that cause musty odours in carpeting) by causing stains and discoloration (such as mildew stains on curtains and tents) or even by deterioration of the fabric itself (some microbes feed on off finishes that are in textiles and others like fungi can eat cotton or latex).

1.1.3 Malodour formation

In the case of textiles the formation of malodour is of particular importance to garments. When microorganisms grow, they metabolize nutrients such as sweat and soiling present in textile products and produce odour-causing byproducts. For example, the metabolism of Gram positive bacteria Staphylococcus aureus is believed to generate 3-methyl 2-hexenoic acid, which is linked to what is considered the characteristic body odour. Gram negative bacteria Proteus vulgaris is known to be able to metabolize urea to form ammonia (Edward, 2001). Apart from the malodour and other problems associated with textiles, microbes cause harm to humans also by transmitting different diseases and infection as well as skin irritation.
1.2 Need for antimicrobial finishes

A recent study in the US showed that three out of four Americans are conscious of germs in their daily lives. This poll indicated that 61% of the women surveyed make an extra effort to buy antibacterial or antibacterial product (Curtis et al., 1997). Articles in textile trade magazines throughout Europe and Asia have reinforced the problems of microorganisms and the desire by the public for the safe ways of solving microbial problems. The use of antimicrobial soaps has been brought into the picture. The antimicrobial treatment becomes highly important for general textiles and high performance applications where the chances of bacterial growth are high and the safety is paramount. They may include medical textiles, sanitary napkins, socks, under garments, disposable wipes, carpets etc (Murugesh, 2003).

Laundering does not necessarily remove all the microorganisms from clothes. Cleansing agents such as soaps and detergents used during laundering reduce the number of microorganisms, but the only sure way to reduce their number to a safe level is to add a disinfectant or antimicrobial agent (Jayashree et al., 2003). Hence antimicrobials are used in textiles to control algae, bacteria, mould, mildew and yeast and to control problems like fabric rotting, staining, unpleasant odours and health concerns ranging from simple discomfort to physical irritation, allergic sensitization, toxic responses, infection and diseases that the presence of microbe can raise (Anita et al., 2002).

1.3 Antimicrobial finishes

Agents which inhibit the growth of microorganisms are labeled as antimicrobial and they are differentiated into bacteriostatic i.e. growth inhibitors and bactericides i.e. bacteria killing agents (Murugesh, 2003). The major classes of antimicrobial agents for textiles include organo-metallics, phenols, quaternary ammonium salts and organo silicones. These finishes should be durable and have selective activity towards undesirable organisms, be compatible with other finishes and dyes and non-toxic to humans (Vigo, 1983). Antimicrobial functions can be conferred on textiles using approaches based on chemical and physical incorporation of biocides (Vigo, 1994; Vigo et al., 1999), potential biocides (Sun and Xu, 1998;
Sun and Xu, 1999) or antibiotics (Cho and Cho, 1997) into polymers. Antimicrobials do not all work the same. The vast majority of antimicrobials work by leaching or moving from the surface on which they are applied. This is the mechanism used by leaching antimicrobials to poison a microorganism. Such chemicals have been used for decades in agricultural applications with mixed results. Besides affecting durability and useful life, leaching technologies have a potential to cause a variety of other problems when used in garments. These include their negative effects because, they can contact the skin and potentially effect the normal skin bacteria, cross the skin barrier and/or have the potential to cause rashes and other skin irritations. A more serious problem with leaching technologies has to do with their allowing for the adaptation of microorganisms (Curtis et al., 1997).

An antimicrobial with a completely different mode of action than the leaching technologies is a molecularly bonded unconventional technology. The bound unconventional antimicrobial technology, an organo functional silicone, has a mode of action that relies on the technology remaining affixed to the substrate killing microorganisms as they contact the surface to which it is applied (Hoon and Sung, 2004). Effective levels of this technology do not leach or diminish over time. When applied, the technology actually polymerizes with the substrate making the surface antimicrobial. This type of anti-microbial technology is used in textiles that as likely to have human contact or where durability is of value (Gettings and Triplett, 1978).

1.4 Scrutiny for antimicrobials

A variety of antimicrobial finishes have now been developed for application to textiles. There are many compounds that fulfill these antimicrobial functions: major families of these include biquanides, phenols and their derivatives, isothiazolones, metals, ammonium compounds and alcohols. Some of the antibacterial agents are based on zeolite, which is an inorganic compound of sodium aluminose used in natural form or produced synthetically. It is widely used in both industrial and consumer applications as a dehumidifying agent, deodorant, absorbent and auxiliary agent for synthetic detergents. Another agent, which is gaining wider use, is triclosan, a phenolic derivative, which is extensively used antimicrobial agent in
many hygiene products such as soap, deodorants, skin creams and toothpaste. Chitin, a naturally occurring substances extracted from the shells of crabs and shrimps, is claimed to have excellent antimicrobial effects used as additive agent, e.g. Chitopoly fibre from Fuji spinning Co. While several bacteriostatic textile finishes already exist for personal wear, their use for this purpose has not received ready acceptance. Poor activity against mould and mildew, lack of wash durability, in adequate safety data to meet the requirements, or a combination of these factors has hampered their use (Gettings, 1985).

This increased demands for antimicrobial products have grown dramatically warrants scrutiny of the antimicrobials being put into the products. There are hundreds and may be thousands of chemistries on the earth (Payne, 1997). Many of these, like arsenic, lead, tin, mercury and silver are highly toxic to people and the environment in most uses (Malek and Speier, 2002). An effective antimicrobial for the textile industry to repel microorganisms, it must do so safely, for the life of the treated products, and without negatively affecting important characteristics of the textiles (Curtis et al., 1997). Antimicrobials differ in their chemical nature, mode of operation, durability, effectiveness, toxicity, safety and cost (Oya, 2003). Hence it is imperative to select the correct antimicrobial textile products.

1.5 Ideal antimicrobial finish

An ideal antimicrobial finish must satisfy the following criteria (Payne and Kudner, 1996).

- Control bacteria or fungi on cloth.
- Effective over the lifetime of the treated article.
- Durable to washing and bleaching.
- No risk of adverse dermal or systemic effects.
- No detrimental influence on fabric properties such as yellowing, handle and strength.
• Compatible with colorants and other finishes such as softeners and resins.
• Low environmental impact of heavy metals, formaldehyde, phenolic and organic halogens.

1.6 Recent advances

In accordance with the outstanding technical innovations, new textiles have entered the realm of functional finishing of textiles (Smith and Block, 1982). Such finishes imply chemical and mechanical processes that impact various performance properties to fabrics that have not existed, for example water repellency, blood repellency, water proofing, abrasion resistant, flame resistance, pesticide resistance or immunity to bacteria or fungi (Trotman, 1984). In general, functional finishes usually need to be durable than normally expected (Conner et al., 1966). Needle punched nonwoven fabrics are the major filters in industries. The kinds of needle punched filter fabrics being produced recently are unique and more particular than ever before (Joseph, 1977). High temperature liquid filter fabrics made from aramid or glass fibres continue to be the popular. Other unique needle punched filter fabrics include those for filtering blood. However, polyester filter bags are what most of the companies in this field are producing (Durso, 1986).

Antimicrobial or antibacterial elements have been making news in fabrics for some time. Starting in the medical field, they gradually colonized the hospitality area, where they are used for bedding and uniforms. From these they moved to sports and hosiery and now the brands are marching on into the high street and major label collections, as the latest way to add appeal for the customer. They are now finding their ways into club wear, as linings for suits, active wear, body wears and socks. Branded antimicrobial treatments are now appearing in major retail brands and fashion collections as an added value quality.

1.7 Multifunctional textiles

Now a days, textiles are passive, mostly mono-functional and single dimensional products, but according to the prognosis, they are going to be active, multifunctional, interactive and multidimensional in the near future. Today’s complex and highly
demanding market is looking for textile end products, which are multi-purpose or have specific or desired properties. The group of smart textiles includes smart fibres with various additives incorporated into their matrix. The selection of additives (Pigments, flame-retardants, antibacterial agents etc.) depends on the fibres end-use and applicability. The process of additives incorporation frequently substitutes conventional finishing processes when textile end products are treated with various finishing agents which also impart new and improved properties to the products but which are usually not resistant enough to rubbing, washing and dry cleaning (Mirjam et al., 2004).

1.8 Eco-friendly operation

Today in the era of eco-friendly operation and use, it has become very important for human being to live in a world of hygiene and freshness. Although there is a need for treating all the garments with antimicrobial finishes, it becomes all the more important for high performance applications where the chance of bacterial growth is high and the safety is paramount such as medical garments, sanitary napkins, socks, underwear, disposable wipes, carpets etc (Edward, 2001). “The polluters must pay” is the concept, which has been emerged recently for industrial production. There are stringent legislations particularly in developed countries on eco-toxicological considerations, health and safety during storage, use and safe disposal of chemicals in water, landfills or release in air during processing or during incineration. In order to meet these requirements, an integrated pollution control approach is essential. This has necessitated having a re-look towards the entire textile production processes. As a result of this some of the well-established chemicals, dyes, finishing agents and auxiliaries have been replaced by environment friendly substitutes for the production of textiles. Consumers, particularly in developed countries prefer eco-friendly textiles. Therefore the manufacturing of textiles in developing countries for the export market in developed countries is oriented towards achieving this goal, though the cost of production is high. Among the various fibres used for apparels, cotton dominates the market due to its several advantages; it is readily available at affordable price compared to silk and wool. Being natural it is considered to be eco-friendly.
1.9 Natural antimicrobials

It is only from the point of view of safety of health and environment that natural finishes have gained momentum. Durable antimicrobial cellulose containing fabrics have a great deal of demand in a country like ours, where temperate climatic conditions especially during rainy season cause immense damage to untreated cotton fabric (Bhawana et al., 2000).

Although several regenerable and durable antimicrobial finishes for cellulose containing fabrics have been developed recently by Gang Sun and co workers (Sun and Xu, 1999) based on the theoretical regeneration model, the functional agent used was a chemical hydantoin derivative. There are few antimicrobial fibres (Kawata, 1998; Stan, 1998) and various antibacterial chemicals (Chemiker, 1995; Payne and Kudner 1996; Karen et al., 1996; Rajendran et al., 1997; Chung et al., 1998; Sun and Xu, 1998; Ha-Soo et al., 1999) available in the international market. But these are all synthetic based, not from the natural sources. There are many plant products, which show antimicrobial properties. The antimicrobial properties have been detected in the chemicals extracted from root, stem, leaves, flowers, fruits and seeds of diverse species of plants. Some of the natural antibacterial products are neem oil (Milan, 1997), clove oil, karanja oil, tulsi oil, cashew shell oil, henna or mehandi.

1.10 Medical textiles

Medical textiles account for a huge market due to widespread need not only in hospitals, hygiene and health care sectors but also in hotels and other environments, where hygiene is required. There has been a sharp increase in the use of natural as well as synthetic fibres in producing various medical products. It is fore casted (Rigby, 1997) that the annual growth of medical textile products is likely to be around 10 %. It is known that microorganisms create and aggravate problems in hospitals and other environments by transmitting diseases and infections through clothing, bedding etc. The axillae and perineal regions of the body are most susceptible to microbial growth that leads to undesirable body odour. It is reported (Vigo, 1994) that polyamide fibres retain more odour causing microorganisms than
natural fibres. Polyester and other synthetic fibres are also prone to the growth of pathogenic microorganisms. Besides microorganisms deteriorate cellulosic fibres and reduce the wear life of the materials (Seventekin, 1993). They adhere to the surface of the fibres; gradually corrode inwards layer-by-layer disintegrating the primary and secondary walls of the fibres causing considerable damage. Fungal growth on textile materials is more rapid at RH greater than 80 % (Vigo, 1994). With the repeated launderings the bacterial propagation increases by about 30 % more colonies on 15 times laundered fabric than the unlaundered ones (Barnes and Warden, 1971). Similarly a large number of fungi have been isolated on exposed cotton textiles (Lewin and Sello, 1973).

1.11 Dual finishes

Hospital materials such as theatre drapes, gowns, masks, sheets and pillow cases are known to be major sources of cross infection, so all textile materials used in hospitals should prevent or minimize infections or transmission of diseases (Vigo, 1981). Currently, there is also a heightened interest in protecting health care workers from diseases that might be carried by patients. Especially for surgical gowns, there is an increasing need to protect medical staff from infection by blood borne pathogens such as HIV and HBV (Leonas, 1993). Gowns should be able to prevent “strike through” or “wetting out” of the fabric (McCullough and Schoenberger, 1991) and so surgical gown materials should have not only antimicrobial properties but also blood barrier properties. Fluoropolymers, most abundantly used as repellant agents in textile finishing not only satisfy the demand for water repellancy but also impart oil and soil repellancy to finished textiles (Lammermann, 1991).

1.12 Microencapsulation

Microencapsulation was developed as a technique over sixty years ago but it is only over the last decade that it has become of interest to textile dyeing, printing and finishing (Ian, 2003). Broadly speaking, microencapsulation may be defined as a micro packaging technique, where in active core material is encapsulated in a polymer shell of limited permeability. “Small is better” would be an appropriate
motto for many people studying microencapsulation, a process in which tiny particles or droplets are surrounded by a coating to give small capsules with many properties (Ramesh and Rane, 2004). In its simplest form, a microcapsule is a small sphere with a uniform wall around it. The material inside the microcapsule is referred as the core, internal phase or fill, where as the wall is sometimes called a shell, coating or membrane (Kirk, 1981). The characteristics of the microcapsule shell depend on the chemical and physical processing conditions. The first significant application of microencapsulation technology was the non-carbon copy paper introduced in 1954 (Arshady, 1989; Benita, 1996; Hong and Park, 1999). The objective of this technology is either to protect the active core material from the external environment till required or to affect the controlled release of the active core to achieve desired delay until the right stimulus is encountered.

Interestingly, microencapsulation process has now attracted the attention of a wide number of industries including pharmaceutical, agricultural, bulk chemical, food processing, and cosmetics as also textiles. The textile industry has been late and slow to react to the possible opportunities this technique could offer. Efforts are still seen more at the research and development stage. Interesting possibilities do exist in medical and technical textiles where this technology could be used for applying finishes and for imparting desirable properties that either or not possible through conventional application procedures are not cost-effective. Some of these examples include, antimicrobial, moth repellancy, flame retardancy etc. Use of phase change materials in the core, has long been suggested for thermal regulation functions in clothing for sports and extreme weather. Although there is a great potential of the microencapsulation technology to succeed in textile area, most applications, as of now are very specific and therefore have limited commercial success. Hence the present study was aimed at the development of natural type of finishes for textile products, which would help to reduce the ill effects and possibly would comply with the statutory requirements imposed by regulating agencies.
1.13 Objectives of the present study

In the light of developments of antimicrobial finishes for the textile products, the present research work was carried out with the following objectives.

- To critically evaluate the efficacy of the commercially available antimicrobial textiles in Coimbatore city of Tamilnadu, India.
- To study the quality attributes of selected medicinal plant extracts as antimicrobial finishes on cotton fabric against the use of chemical agents such as chitosan, infasil and tinosan.
- To validate and optimize the use of different plant extracts, post treated with cross-linking agents and evolve an eco-friendly cross-linking agent.
- To assess the effect of a dual function finish containing antimicrobial properties and blood repellancy on cotton fabrics and validate as medical textiles.
- To evaluate the microencapsulation techniques for the slow release of antimicrobial factors and enhance durability using gelatin and alginate polymers.
- To standardize the process parameters (process optimization) using Box-Behnkens statistical tool for practical bulk cotton fabric application and to validate their antimicrobial, physical, fastness and functional properties using standard American Association of Textile Chemists and Colorists (AATCC) test method and other international standard methods.