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ECOFRIENDLY AND NATURAL ANTIMICROBIAL FINISHES FOR TEXTILES

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Abstract-Textile fabrics made of natural fibres such as cotton, wool, silk etc. are liable to microbial attack and as a result they are found risky for various health and hygienic applications as well as for daily use. Therefore, there are researches going on in various dimension for preparation of anti-microbial textiles. Other than conventional methods of preparation of the same by treating textiles with some inorganic agents like $CuCl_2$, quaternary ammonium salts, halamines etc. there aresustainable method by coating textiles with natural bio-extracts such as neem, aloe vera, tulshi etc. as well as most recently, coating with conductive polymers like polypyrrole, polyaniline etc. and which are found very promising as a sustainable and green approach.

Keywords: [Textile fabric, microbe products, antimicrobial textile.]

1. INTRODUCTION

Textiles are an excellent medium for the growth of microorganisms when the basic requirements such as nutrients, moisture, oxygen, and appropriate temperaturepresent. The large surface area of textiles also assists the growth of microorganisms on the fabric. Natural fibers are more susceptible to microbial attack than synthetic fibers. Protein fibers act as a nutrient source for moth worms.Cellulosic fibers themselves are not a direct source of nutrients but, under appropriate conditions, some fungi secrete enzymes that convert cellulose into glucose a nutrient source for microorganisms[1]. Soil, dust, and a few textile finishes can be a source of nutrients for microorganism.Synthetic antimicrobial agents are very effective against a range of microbes and give a durable effect on textile. There are a number of demeritsofsynthetic antimicrobial agentsincluding poor wash fastness, water leaching as well as toxic effect on human and other living beings. So, there is a great demand for antimicrobial textile based onecofriendly agentswitch not only help to reduce microbial growth on textile materials but also fulfill requirements imposed by recognize agencies towards sustainability and eco-friendliness[2].Today, in the era of eco-friendly operation, it has become very important for human beings also to live in a world of hygiene and freshness. The major hindrance that comes in their way is microorganisms, which are the causative agents of deterioration, staining and odour. Apart from this,the microbes cause harm to human being by transmitting various diseases and infections. So, it becomes very important to finish all garments with ecofriendly anti-microbial agents where there is no chance of bacterial growth and the safety of end-use is paramount.

2. ORIGIN OF ANTIMICROBIAL TEXTILES

During World War II, when cotton fabrics were used extensively for tent, tarpaulins and truck covers.These fabrics needed to be protected from rotting caused by microbial attack. This was particularly a problem in the South Pacific campaigns, where much of the fighting took place under jungle like conditions. During the early 1940's, cotton duck, webbing and other military fabrics were treated with mixtures of chlorinated waxes, copper and antimony salts thatstiffened the fabrics and gave them a peculiar odour. After World War II, fungicides used on cotton fabrics were compounds such as 8-hydroxygiunoline salts, copper ammonium fluoride and chlorinated phenols. As the government and industrial firms became more aware of the environmental and workplace hazards these compounds caused, alternative ecofriendly products were sought[3].

3. FUNCTIONS OF ANTIMICROBIAL TEXTILES

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

4. PURPOSE OF ANTIMICROBIAL FINISH

A. **Rot proofing** is an antimicrobial finish applied to givenmaterialfor protection either long term or short term against physical deterioration.

B. **Hygiene finishes** are concerned with the control of infection and unwanted bacteria; aspecialized development is the prevention of dust mites.

C. **Aesthetic finishes** are used to control odour development and staining.

5. TYPES OF BACTERIA AND CLASSIFICATION OF ANTIMICROBIAL AGENTS

Microorganism are small living forms of life, which we cannot see with the naked eye as shown in figure: 1

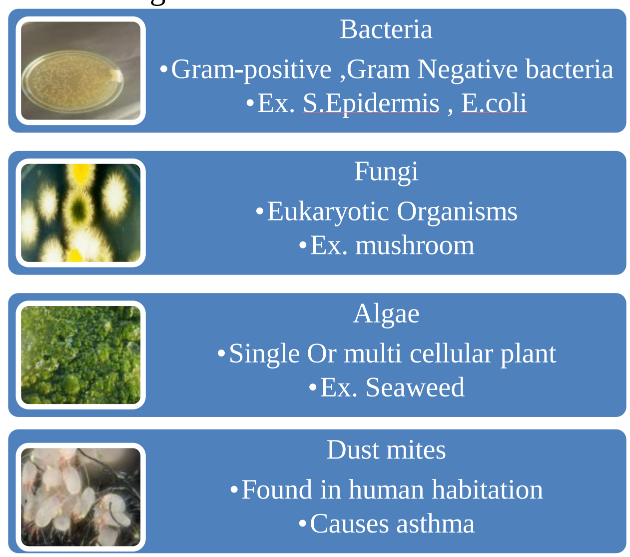

Figure 1. Various types of microorganism

The antimicrobial agents are classified broadly in two types viz. leaching types and non-leaching types.

5.1 Leaching type or conventional antimicrobials

These products diffuse from the garment to come in contact with microbe. They migrate off the garments, forming a sphere of activity and any microbes coming into the sphere are destroyed. But in the course of time the strength decreases and thus, it just 'hurts' the microbes, giving them a chance to form a strain by mutation.The microbes consume the antimicrobials as it acts on them. The productshare eventually used up by the bacteria and slowly losestheir effectiveness.

5.2 Non leaching type

These agents arebound to the product, allowing control of the microorganisms.Products do not migrate off the garments and destroy thebacteria coming in contact with the surface of the garment.The microbes do not consume the antimicrobials, theydestroy them by acting on the cell membrane.The finishing will the permanent and will remain functional through the life of the fabric will withstand more than 40 laundry washes.

6. TYPES OF ANTIMICROBIAL AGENTS ACCORDING TO ACTION AGAINSTMICROORGANISM

Current antibacterial agents falls under two categories as following. (a) Biostaticdrugs those inhibit the growth of microorganisms; microorganisms including for example, bacteria, fungi and viruses[4]. (b) Biocidal drugs thosekill microorganisms by generating hydroxyl radicals through a common oxidative reaction and damage cellular death pathway involving alterations in central metabolism and iron metabolism[5]. Bactericidal agents kill bacteria with an efficiency of >99.9%.These antibacterial agents work on three fundamental mechanisms viz. inhibition of protein synthesis, inhibition of DNA replication and repair or inhibition ofcell-wall turnover.

6.1. Inhibition of protein synthesis: The process of mRNA translation occurs over three sequential phases (initiation, elongation and termination) involving the ribosome and a host of cytoplasmic accessory factors 84. The ribosome organelle is composed of two ribonucleoprotein subunits, the 50S and 30S, which organize (initiation phase) on the formation of a complex between an mRNA transcript, fMet-charged aminoacyl-tRNA, several initiation factors and a free 30S subunit 85. Drugs that inhibit protein synthesis are among the broadest classes of antibiotics and can be divided into two subclasses: the 50S inhibitors and 30S inhibitors[6].

6.2. Inhibition of D.N.A. replication and repair

Antibiotic-induced cell death has been associated with the formation of double-stranded DNA breaks following treatment with DNA gyrase inhibitors. Modulation of chromosomal supercoiling through topoisomerase-catalyzed strand breakage and rejoining reactions is required for DNA synthesis, mRNA transcription and cell division. These reactions are exploited by the synthetic quinolone class of antimicrobials, including the clinically-relevant fluoroquinolones, which target DNA-topoisomerase complexes· Quinolones are derivatives of nalidixic acid, which was discovered as a byproduct of chloroquine (quinine) synthesis and introduced in the 1960s to treat urinary tract infections. Nalidixic acid and other first generation quinolones (i.e.oxolinic acid) are rarely used today owing to their toxicity. However, these bacteriostatic drugs predominantly inhibit ribosomefunction, targeting both the 30S (tetracycline family andaminocyclitol family) and 50S (macrolide family and chloramphenicol) ribosome subunits.Theaminocyclitolgroup of 30S inhibitors includes the bactericidal aminoglycosidefamily of drugs and the bacteriostatic drug spectinomycin; the aminoglycoside family, excluding spectinomycin,is the only class of ribosome inhibitors known tocause protein mistranslation.With regard to other classes of bactericidalantibiotics, quinolones target DNA replication and repairby binding DNA gyrase complexed with DNA, which drivesdouble-strand DNA break formation and cell death as shown in Figure 2.[5][6].

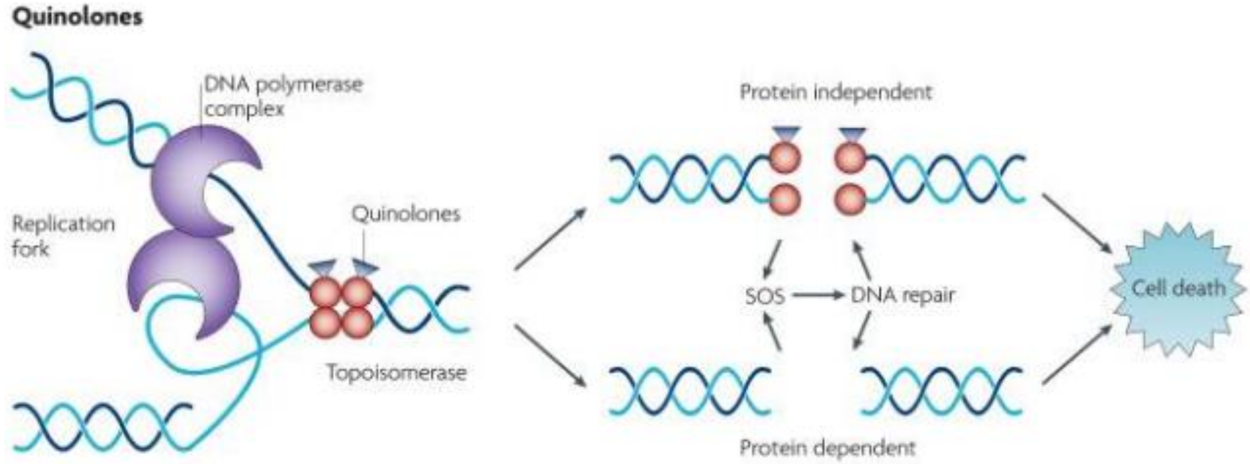

Figure 2. Mechanism of antimicrobial effect by inhibition of DNA replication and repair

6.3. Inhibition of cell wall synthesis

Cell-wall synthesis inhibitors (such as blactams),interact with penicillin-binding proteins and glycopeptides that interact with peptidoglycan building blocks and interfere withnormal cell-wall synthesis and induce lysis and cell death as shown in Figure 3.Treatment with a cell wall synthesis inhibitor can result in changes to cell shape and size, induce cellular stress responses, and culminate in cell lysis.

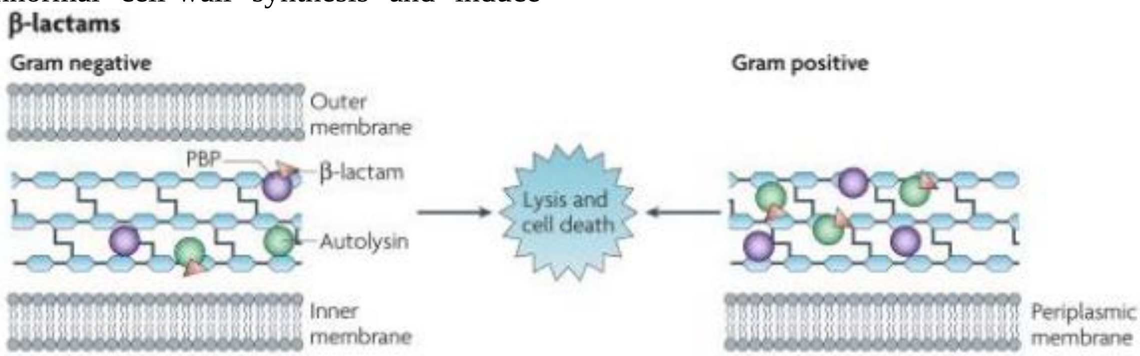

Figure 3. Mechanism of antimicrobial effect by inhibition of cell wall synthesis[6].

7. APPLICATIONS APPROACHES OF ANTIMICROBIAL AGENTS ONTO TEXTILES

There are various approached by which antimicrobial agents are incorporated of applied in textiles. One of the method is called **internal antimicrobial release**where antimicrobial agents are incorporated into thesynthetic fibres during spinning. As a result fibre itself become intrinsically antimicrobial material that can release antimicrobial agent internally[7].Another approach is **surface application of antimicrobial finish**that is universally applicable for all types of fibers. But the washing durability depends on the affinity of antimicrobials towards the fibre substrate. How strong the polymers can bind with the textile surface decides durability of the finish.Ionic charge could be another factor to consider for certain fibers, such as PAN.**Chemical bonding** is a third approach and that is theoretically the best way to achieve durability and it works well on cellulose, wool and polyamidefibres. However, this method requires suitable reactive groups on the fibers to work effectively.

8. ECOFRIENDLY AND NATURAL ANTIMICROBIAL AGENTS

Other than conventional methods of preparation of the same by treating textiles with some inorganic agents like $CuCl_2$, quaternary ammonium salts, halamines etc. there are sustainable method by coating textiles with natural bio-extracts such as neem, aloe vera, tulshi etc. as well as most recently, coating with conductive polymers like polypyrrole, polyaniline etc. and which are found very promising as a sustainable and green approach.

8.1. Neem(Azadiracta indica)

Neem (Azadirachta indica) is an evergreen tree of India, and recognized as one of the most promising sources of compounds with insect control, medicinal[8].and antimicrobial properties. The active ingredients of neem are found in all parts of the tree but in general, seed, bark, leaves and roots are used for extraction purpose[9].More than 300 different active compounds have been reported from different parts of neem tree but, the most important limonoids are azadirachtin, salannin and nimbin (Fig 4). The neemextracts have been widely used in herbal pesticide formulation because of its pest repellent properties has a potential to inhibit growth of bacteria both Gram positive and Gram negative.A systematic study on integrating neem seed and bark extracts to cottonwasreported. Figure5,[10]shows the photographs of bacteria colony forming unit of Bacillus subtilisbefore and after the finishing treatment of cotton/polyester blend fabric with neem seed extracts. Table 1.[11]shows the percentage effectiveness of various concentration of neem extracts against killing bacteria.

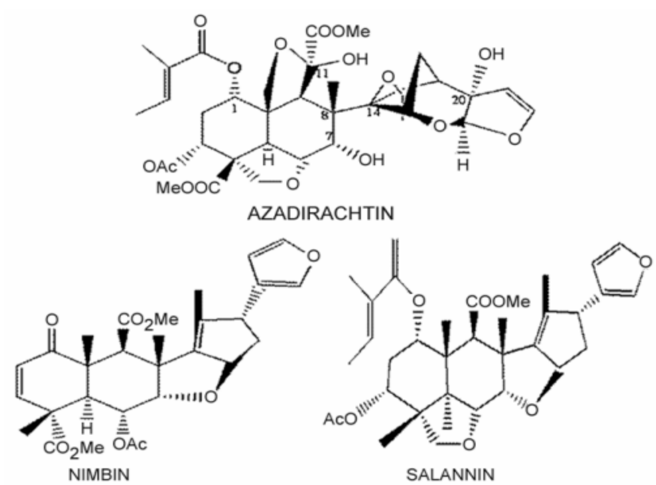

Figure 4. Active limonoids in neem extract

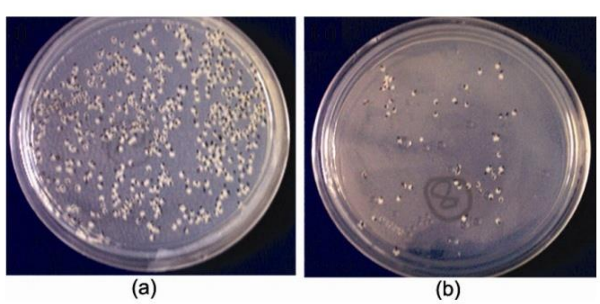

Figure 5.Photographs of (a) untreated and (b) neem seed extract (5%w/v) treated cotton (against B. Subtilis bacteria).

SAMPLE	Escherichia Coli		Bacillus	
	3% neem extract finish	5% neem extract finish	3% neem extract finish	5% neem extract finish
Without Wash	30.66	39.77	31.55	41.89
1st wash	11.93	15.49	20.86	25.92
2nd wash	10.48	15.01	18.04	20.91
3rd wash	10.21	13.75	11.18	13.31
4thwash	9.51	11.28	11.02	8.32
5thwash	9.02	11.92	5.93	8.49

Table 1. Percentage effectiveness of neem leaves extract coated fabric

8.2 ALOE VERA

Aloe vera (Aloe barbadensis, Miller) has been used as a skin care product for more than 2000 years. In modern times, scientific research has shown that the Aloe leaf contains over 75 nutrients and 200 active compounds, including 20 minerals, 18 amino acids and 12 vitamins[12]. Aloe vera possesses antifungal and antibacterial properties, which can be exploited for medical textile applications, such as wound dressing, suture, bioactive textiles.

There are different polysaccharides in Aloe vera, such as glucomannan with different molecular weight, acetylated glucomannan, galactogalacturan, glucogalactomannan with different composition as well as acelylated mannan or acemannan.Acemannan a long chain polymer consisting of randomly acetylated linear D-mannopyranosyl units has immunomodulation, antibacterial, antifungal and antitumor properties.

Aloe vera extract at various concentrations (5, 10, 15, 20 and 25gpl) was applied on cotton fabric in presence of ecofriendlycross-linking agent glyoxal (100gpl) by pad-dry-cure technique. Both the qualitative (AATCC-147- 1998) and quantitative (AATCC-100-1998) evaluation was done to assess the degree of antibacterial activity of the Aloe vera treated cotton fabric.Absorbance of the sample is directly proportional to the concentration of the cells in the sample. The absorbance values at 600 nm for the untreated and treated samples were compared (Table 2)[13].It has been observed that as untreated fabric is treated with increases concentration of aloe vera gel absorption value decreases which denotes less number of bacteria cell present in the solution.

S.no	Sample	absorbance value
1	Untreated	1.02
2	5% gel treated	0.94
3	75%gel treated	0.93
4	100%gel treated	0.89
5	Commercial gel treated	0.97

Table 2. Absorbance test at 600 nm wavelength for estimating antimicrobial effect

8.3 Tea tree

Tea tree (Melaleuca alternifolia) is native to the north coast of New South Wales. The oil of tea tree brings together over 100 different compounds and recognized as a natural medicinal product. It has antiseptic (five times stronger than the usual household disinfectants), dermatological (prevents dry skin), and anti-fungal benefits and can also be used to fight infections/ infestations [14]. Its oil is considered to have some of the best natural antiseptic / antifungal properties in the world. The oil is active against a wide range of bacteria, such as Escherichia coli, Propioibacteriumacnes, Proteus vulgaris, Pseudomonas aeruginosa,Staphylococcus aureus, Proteus mirabilis, Salmonellatyphimurium, Streptococcus pyogenes, Helicobacterpylori, etc.

8.4 Tulsi leave

Basil or tulasi (Ocimum sanctum L.) is considered as a sacred plant and its various medicinal properties have been mentioned in ancient medicinal text, Ayurveda. Different parts of this plant are used for treatment of various ailments. The chemical constituents of essential oil obtained from fresh and dried leaves differ greatly thus, it may differ in biological activities too. The activity of essential oils obtained from fresh and dried leaves of O. sanctum against clinical isolates of enteric bacteria i.e., Escherichia coli, Shigella sp. and Salmonella typhi and yeast (Candida albicans). The major ingredients that are responsible for antimicrobial effect are tabulated in table 3[15].

Major constituents	% in Fresh leaves oil	% in Dried leaves oil
Eugenol	57.94	6.34
Beta-Caryophyllene	15.32	18.20
Beta-elemene	7.57	11.38
GermacreneD	9.10	3.24
Caryophyllene oxide	3.20	29.36

Table 3. Major chemical constituents of the essential oil of Tulsiused in antimicrobial study.

8.5 Other natural Bio-extracts

Clove oil (eugenol) is a main product of Syzygiumaromaticum. Bioactivity of clove oil was explored in size paste as size preservative as well as finishing agent for cotton textiles to make it antibacterial. The wash fastness of the finished fabric was improved by using dimethyloldihydroxyethylene urea based inbuilt catalyst (KVSI)[16]. In a study, Sarkar et al showed that clove oil with 0.5% conc. shows 17 mm of zone of inhibition using Staphylococcus aureus andKlebsiella pneumonia, whereas cotton fabric treated with 1% clove oil (along with KVSI) shows 47 mm zone of inhibition against Staphylococcusaureus (Gram positive) bacteria.The antimicrobial activity of five different solvent extracts of four Indian nutraceutical plants viz. Manilkara zapota (L.) var. Royen., Psidium guajava L., Punica granatum L. and Syzygiumcumini L. leaves against 14 pathogenic microorganisms[17]. The antimicrobial activity was evaluated by agar well diffusion method. P. guajava leaves showed best and promising antimicrobial activity, indicating the possibilities of its potential use in the formula of natural remedies for the treatment of infections.

9. CONDUCTIVE POLYMER COATED TEXTILES FOR ANTI-MICROBIAL EFFICACY

In 2005, Seshadri and Bhat first reported antibacterial activity of π-conjugated polymers. It is a novel method of developing antimicrobial textiles by coating textiles with conjugated polymers like polypyrrole, polyaniline, polythiophene etc. which are found very promising as a sustainable approach.The mechanism of antimicrobial activities is suggested to be a due attack on the cell wall of the bacteria by the charged nitrogen and chloride ions of polypyrrole.

Polypyrrole coated cotton fabric showed a 65% reduction of gram-positive bacteria and

59% for gram-negative bacteria and 73% for a fungal culture which is boosted by the addition of another antimicrobial agent viz., $CuCl_2$ as shown in Table 4[18].

Sample	Microbial Reduction (%)		
	Staphylococcus Aureus	Escherichia Coli	Candida Albicans
Cotton +PPy	64.86	59.14	73.07
Cotton +PPy+$CuCl_2$	92.53	97.60	100.00

Table 4. Anti-microbial properties of PPy treated cotton fabrics.

Advantage of using polypyrrole is that it is insoluble in water unlike quaternary ammonium salt and halamines, and it is biocompatible and non-toxic in nature. Therefore, good antibacterial activity against S. aureus and E. coli bacteria has been observed by polypyrrole-coated cotton fabrics.

10. GLOBAL SCENARIO FOR THE ANTIMICROBIAL TEXTILES

The total global market for biocides for 2006 is expected to be approximately $400 million U.S. dollars. The highest consumption of antimicrobial by application is in the architectural market, including interior and exterior coatings which are designed to provide protection from growth of molds and mildews. Other markets which are expected to see growth forantimicrobial coatings include hospitals, nursing homes, daycares, and medical applications where high standards of hygiene are required. [19] The US disinfectant and antimicrobial chemical market will grow five percent annually through 2009 based on concerns about bacterial and pathogenic threats. Phenolic compounds, nitrogen compounds and organometallics will remain the topproducts.

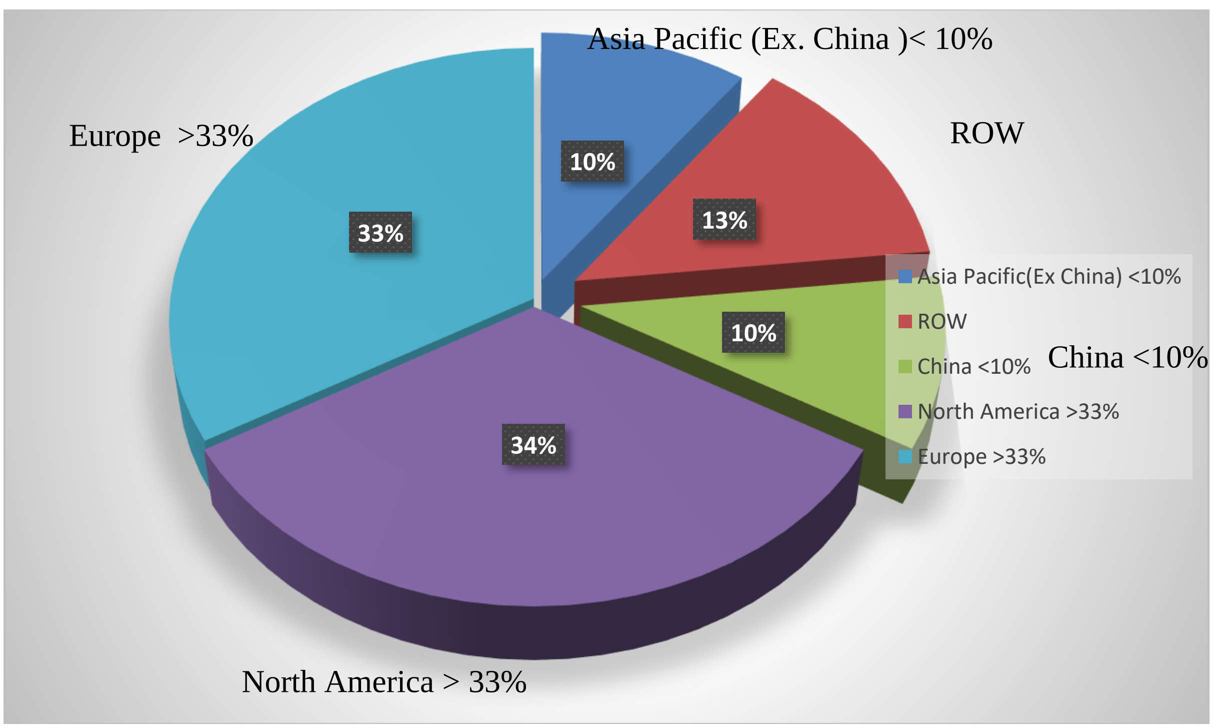

Figure 6. Market size of Biocides

CONCLUSIONS

There is a vast resource of natural antimicrobial agents, which can be used for imparting usefulantimicrobial property to textile substrates. Although, there are many cited literature, wherein efforts have been made to exploit these ecofriendly bioactive natural products for textile application, but there are very few studies which have carried out systematic in-depth investigation. The major challenges in application of natural products for textile application are that most of these biomaterials are complex mixtures of several compounds and also the composition varies in different species of the same plant. The activity and composition also vary, depending on their geographical location, age and method of extraction. The availability of these products in bulk quantities, their extraction, isolation and purification to get standardized products are other challenges in their application. The durability, shelf life and antimicrobial efficiency vis a vis synthetic agents are other issues, which need to be looked into. However, because of their ecofriendly nature and non-toxic properties, they are still promising candidates for niche applications such as medical and health care textiles.

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