CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

The word "bio-medical" refers to the engineering design and technology utilised in medical equipments used by living things. While "Bio-medical Textile" refers to textile items and structures created for the use in biological and medical purposes. These items have been proven to be highly helpful in first aid for both clinical and sanitary purposes [1,2]. The material's hygiene behaviour when being utilised for medical purposes is crucial. Numerous studies have been conducted on the hygienic properties, in particular the antibacterial properties of the medical textiles used in goods like gloves, masks, caps, etc. that come into close contact with human skin [3]. Bio-medical textiles have covered wide application range to aid diverse objectives. The major provinces include uniforms worn by staff members and operating drapes by surgeons as a protective medium; bandages, pressure garments, prosthetic socks, etc. as medical aids. Also sutures used as an external device; vascular grafts and artificial ligaments used as implantable materials; diapers, sanitary towels, and incontinence pads, as hygiene products and an artificial liver, kidney, and lung, and so on, are used as an extracorporeal device. The structure of a biological textile relies on the basic requirement(s) of its intended use. The prime considerations in their engineering are function, biocompatibility, cost, and product approval. Indeed, for medical textiles, each country has laid down its own laws and requirements; one must have to adhere them strictly.

The nonwoven based bio-medical textiles are ever remained the material of choice for many tissue engineering and regenerative medicine applications. Their exceptional surface area, high void volume, great permeability, and low production cost are the key factors for such favour. Till date they have served a broad range of applications starting from aesthetic surgery include; surgical mask, surgical gowns, surgical drapes, surgical gloves; hospitals bed sheets, scaffolds, dental, cosmetic applications, and wound care to orthopaedic repair [4]. Most significantly, it enables customizable performance and regulated absorption profiles by promoting cellular in-growth through precise spacing, layer thickness, and material integrity [5].

Nanoparticles can be synthesized via techniques, like; nucleate and develop particles from fine molecular distributions in liquid or vapour phase. Synthesis can also comprise functionalization by conjugation to bioactive molecules like silver, copper, zinc etc. Such biologically active metals, known as bio-metals are known to human beings since long back in the form of “grandma recipe”. Salts, complexes, colloid particles, “silver” water were commonly used house hold remedies for antimicrobial, bactericidal in many dieses [5].

Chemical and Physical synthesis of nanoparticles on the basis of metal oxides or intermetallic oxide compounds, such as TiO_2, SnO_2, ZnO_2, and SiO_2 are creative and novel approaches sourced by modern scientists to develop sophisticated antibacterial and antiviral nano-systems. These compounds have functionalized molecular structures that are organic or organometallic and may join the ions of transition bio-metals like Ag+ and Cu++. Such methods may be utilised to produce both medicinal and non-medicinal products, dermatological chemicals and lotions, as well as bactericidal modified surfaces and coatings in residential, commercial, and industrial settings [5,6]. Due to its proactive performance, silver nano ($AgNO_3$) colloidal, a chemically synthesised antibacterial agent, has continuously been preferred over other antibacterial components for imparting desirable hygienic activities in manufacturing non-woven based nano-composites [7]. These composites are frequently utilised in the production of bandages, gloves, gowns, aprons, and other bio medical textile items.

Despite their effectiveness, chemical and physical approaches have a number of shortcomings. The chemical and physical processes produce poisonous by-products, hazardous waste and using a lot of energy resources. Recent studies have shown that chemically produced nanoparticles may include hazardous compounds, rendering them less-than ideal for biological uses. By using entirely green methods or biologically synthesising nanoparticles, problems with energy balance and hazardous by-products have been resolved. A variety of biological resources, including plants, microbes, algae, and yeasts, are utilised for the goal of being [8]. Because of its low cost, speed, solitary synthesis, high yield, and biocompatibility, biosynthesis is preferable to alternative methods. Additionally, the concentrations, pH, and temperature may be easily adjusted to regulate the size [5]. In the current situation, plants and plant products have found primacy over the other possibilities in the biosynthesis of nanoparticles due to their wide availability, low cost, and rich source of bio-reducing agents.

1.2 RESEARCH GAP:

Since long back silver nanoparticles (AgNPs) have shown exceptional efficacy in the bio-medical field and chemical reagents like sodium borohydride are responsible for their long-term stability at the nanoscale. The usage of natural, eco-friendly reducing and capping agents, such as extracts of tulsi, neem, aloe vera, etc., are analysed and promoted constantly for this purpose owing to the application situation where textile silver nano-composite is going to come into direct touch with human body.

The prevalent usage of CP (Calotropis procera, Milkweed) leave for treating burns, fungal infections, and wound healing in rural regions is age old practice and widely documented. It possesses a high amount of naturally occurring antibacterial potential which is yet not been scientifically explored in conjunction with textile materials, with or without well-established silver nano.

1.3 OBJECTIVES OF RESEARCH:

The present study has been designed to develop and optimize green synthesis technique for AgNPs using CP leave and gauge the performance of the prepared prototype antibacterial nonwoven @AgNPs/CP nanocomposites for various bio-medical applications. The goals set up for the research are:

a) Lab-scale production of the silver nanoparticles and their validation via chemical and green synthesis techniques.

  i) Elementary investigation of the AgNPs produced by a chemical synthesis technique.
  ii) Elementary investigation of the AgNPs produced by a CP extract based green synthesis technique.

b) Application of bio-synthesized AgNPs on nonwoven fabric and Confirmation of Nano-composite's antibacterial activity.

  i) Loading bio-synthesized AgNPs on a PV (Polyester-Viscose) non-woven to produce nano-composite textile materials.
  ii) Confirming antibacterial activity of PV-AgNPs/CP nanocomposite.
  iii) Evaluating characteristics of the nanocomposite by ESEM, EDAX, Nanoparticles size distribution, FTIR, Physical parameters e.g. GSM and Thickness; Low-stress properties e.g. Bending modulus and Crease recovery

angle; Comfort-related properties e.g. Air permeability and Overall moisture management capability (OMMC); and UV Transmission properties.

c) Investigating optimum feed levels for the constituents in the AgNPs/CP colloidal synthesis based on antibacterial activities potential in nonwoven @PV-AgNPs/CP Nano-composites.

i) Major scale add-on trials

ii) Minor scale add-on trials

d) Development of nanocomposites using optimum AgNPs/CP colloidal and the best 10% CP extract with popular nonwoven base materials and evaluating their basic physical, low stress, comfort associated as well as functional properties as per ASTM standards.

1.4 RESEARCH IN BRIEF:

The entire experimental work was divided into four phases for the step-by-step evaluation of the newly designed product.

The first phase of study was designed for elementary investigation of the silver nanoparticles; synthesized via commercial chemical technique and pioneering green channel; using Calotropis Procera (CP) leave extract using forward, reverse and reduction approaches. The reverse method (Bottom-up approach) has produced excellent nanoparticle during green synthesis in line with the chemical technique. The preliminary but subjective colour change observation and SEM analysis both have confirmed successful formation of desirable nanoparticles on green-way synthesis.

The second phase was designed to develop the prototype eco-friendly nano-composites for medical health care applications. The simple and effective cold dipping technique was used for AgNPs/CP under in-situ deposition on PV-Nonwoven; the most popular bio-medical textile material. The EDAX and FTIR test results have confirmed presence of AgNPs in PV-nonwoven structure on treatment. Whereas, the ESEM images have endorsed a virtuous deposition of AgNPs on the PV-nonwoven by even covering of constituent fibres. Antibacterial activity potential was realized from the significant antibacterial activity noted against both the bacterial cultures Staphylococcus aureus (23.75mm) and Escherichia coli (24.5mm) for the newly engineered PV-AgNPs/CP material.

The favourable shift in moisture management, low-stress, and comfort-related characteristics were detected on loading of AgNPs/CP.

After realizing efficacy of novel green channel, the third phase of experimentation was conducted to optimize qualitatively and quantitatively silver nitrate ($AgNO_3$) salt add-on and CP leave extract concentration during synthesis process. Major scale and minor scale add-on pilot trials were conducted for the purpose being and synthesized colloidal were analysed for nanoparticle formation and stability, particle size analysis and antibacterial activities. They were also checked for the susceptible toxicity of the participating elements by MTT assay cytotoxicity test. The sorted optimized combination was further evaluated for its antibacterial efficacy into prototype PV based bio-medical nonwoven nano-composite. The colloidal solution E10S0010 produced with 10% CP leave extract and 10mM $AgNO_3$ was found optimum with formation of a very good nanoparticle size distribution of 25.8nm. This was also endorsed by its UV-visible spectra showing a narrower and more (sharp) strong peak with maximum absorption in the wavelength range 400–450nm. The nanoparticles have retained their stability well up to six month and possessed substantial 84% cytotoxicity. The optimum PV-AgNPs/CP nano-composite has exhibited the highest average ZOI value, with 18.0mm against SA and 21.7mm against EC bacterial culture. Contribution of optimal green medium in the success of AgNPs/CP performance was also analysed. The GC-MS analysis of the optimum 10% concentrated CP leave extract has revealed the presence of N-Decanoic acid ($C_{10}H_{20}O_2$) responsible for antibacterial activity as well as other components contributing effectively for reduction and capping of the nanoparticles. The extract has shown 92% cell viability during the MTT assay as well as significant antibacterial activity against SA (16mm) and EC (19.3mm) bacterial cultures.

The novel and ecologically strengthened AgNPs/CP nonwoven composites for vivid bio-medical applications were worked out in the fourth phase of the study. Two most popular bio-medical textile materials; PP-Nonwoven and PV-Nonwoven of their commonly used GSM; PP30, PP45, PP50 and PV40, were used as base materials for the purpose being. The innovative composites were meticulously evaluated for their basic physical, comfort-related, morphological, and elemental as well as the targeted antibacterial potential. Efficacy of CP leave extract in the absence of AgNPs in the nonwoven composites was also worked out in parallel. It was noted that GSM as well as thickness has shown significant increase at the nano-level AgNPs/CP loading mainly due to participating heavier silver particles. This was substantiated by the non-significant changes noticed on loading only CP leave extract in each case. The similar behaviour was noticed for comfort-associated and low-stress properties. However, the resultant values in either of the cases were well within the acceptance range for the targeted end uses. The favourable significant rise in UPF value has been noticed on AgNPs/CP loading invariably for all the samples under consideration. ESEM and FTIR have endorsed presence and desirable uniform distribution of AgNPs in the constituent fibers for all the base textile materials. All together has resulted into good antibacterial efficacy for the selected samples. Apart from these, only CP treated nonwoven textile materials also have shown remarkable antibacterial activity due to its inherent chemical constituents as mentioned in phase-III for GC-MS test results.

The innovative CP based green synthesis of AgNPs and its incorporated both PP based as well as PV based nonwovens have shown targeted sustainable antibacterial efficacy along with other physical, mechanical, low-stress and comfort-associated characteristics. Thus, it has opened new horizon for ecological bio-medical textile materials preparation technique.