Effect of Different Types of Spunlace Nonwoven on Wound Pads Exudates Handling Capacity Characteristics

By

Keerthana. M

(16PBX002)

A Thesis submitted to the

Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore-641 043

In Partial Fulfillment of the Requirements for the Degree of

Master of Science

in

BioTextiles

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Certified as Bonafide Research Work

10.4.2018

Signature of the
Head of the department

9/4/18

Signature of the Guide

ACKNOWLEDGEMENT

The investigator places her humble salutations and prayer to the **ALMIGHTY GOD** for his uncountable blessings showered upon her throughout the study.

The investigator expresses her sincere thanks to the former chancellor of Avinashilingam Institute for Home Science and Higher education for women, Coimbatore, **AYYA THIRU. Dr. T .S. AVINASHILINGAM** and former vice chancellor **HONY. COL.PADMASHRI, AMMA, Dr. (Tmt). RAJAMMAL P. DEVADAS,** M.A., M.Sc., Ph.D.(ohio state), Hon. D.SC. (Azad Agri. University, Kanpur), for their heavenly blessing.

The investigator expresses her sincere thanks to **PadmashriDr.P.R.KRISHNAKUMAR,**Chancellor, Avinashilingam Institute for Home Science andHigher Education For Women, Coimbatore, for providing the infrastructural facilities for the conduct of the study.

The investigator is indebted to **Dr. (Mrs.) PREMAVATHY VIJAYAN**, M.Sc., M.Ed., Dip.spl.Edn.M.Phil.,Ph.D., Vice-Chancellor, Avinashilingam Institute for Home Science and Higher Education For Women, Coimbatore, for providing all the amenities required for the conduct of the study.

The investigator records her gratitude to **Dr. (Mrs.) S.KOWSALYA,** M.Sc., M.Phil., Ph.D., Registrar, Avinashilingam Institute for Home Science and Higher Education For Women, Coimbatore, for providing all the help for the smooth conduct of the study.

The investigator records her respectful tribute to **Dr. (Mrs.) N.VASUGIRAAJA, M.Sc., M.B.A., M.Phil. (Madras), Ph.D.,** Dean, Faculty of Home Science,Professor, Department of Textiles And Clothing, Avinashilingam Institute for Home Science and Higher Education for Women, Coimbatore, for constant support , guidance and encouragement which have helped in the successful completion of this study.

She expresses her respectful regards and sincere thanks to **Dr. (Mrs.) S.AMSAMANI, M.Sc., M.Phil., Ph.D.,** Professor and Head of the Department,Department of Textiles and

Clothing, Avinashilingam Institute for Home Science andHigher Education for Women, Coimbatore, for rendering all help needed for the successful completion of the study.

The investigator feels extremely proud and privileged for having worked under the guidance of her esteemed guide **Dr.(Tmt) K.KALAIARASI**, M.Sc., M.Phil, Ph.D., Assistant Professor, Department of Textiles and Clothing, Avinashilingam Institute for Home Science and Higher Education For Women, Coimbatore, for her constant motivation, keen interest, restless support, untiring patience, innovative ideas, suggestions, constant love and easy approach throughout the study.

She also wishes to thank all the **TEACHING AND NON TEACHING STAFF**members of the department of Textiles and Clothing for their help to carry out the research work.

I extend my sincere thanks to **Dr. PRAKASH VASUDEVAN**, Director – South India Textile Research Association (SITRA) and **Dr. KETAN KUMAR VADADORIA**Head of the Department – Coe Medical Textile SITRA for permitting to carry out the project and for their timely help for the study.

It's the privilege and honor to extend the gratitude to **Mr. T. SURESHRAM** Senior scientific officer department of physics- COE (centre of excellence for medical textiles), South Indian Textile Research Association (SITRA), for his guidance encouragement, motivation and inspiration throughout the course of study.

I take immense pleasure to thank **Mr. S. RAVICHANDRAN, Ms. R. SHANTHI, Mr. S. SANGRAM** COE – physical laboratory and otherstaffmembers of COE SITRA for their incredible help, encouragement, patient and cooperation in carrying out the thesis work. Their kind support and timely help have been a great value for complete the research work.

The investigator gratefully acknowledges the encouragement, timely help and support received from her friends. She expresses her deepest sense of gratitude to her **BelovedParents, Family members and Friends** for extending their support without whom the studywould never have seen the light of the day.

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1. INTRODUCTION

Combination of textile technology and medical sciences has resulted into a new field called medical textiles. Medical textiles is the rapidly growing part of the textile industry. This growth is attributed to the continuous improvements and innovations that have been made in both textile and medical field. Health is always one of the prime concerns of human beings. Wounds are a chief cause of ill health of patients and cause major cost to public healthcare providers and hospitals (Fletcher, 2010 and Cook, 2011). Unhealthy conditions and infections make wound healing a complex process during its different phases. (Arun et al., 2013). Approximately 1-2% of the population suffers to heal wounds during their lifetime which require special dressings that promote an optimal healing environment. The most important consideration is to match the wound with appropriate dressing that correlates to size, type of wound, volume and viscosity of the exudates present. The wound care dressings are one among that remarked as products with significant growth in the upcoming years (Reichenberg and Davis, 2005). Among the enormous medical textile products bandages and wound dressings gained larger popularity.

According to the type, amount and viscosity of exudate wound dressing should be selected. The dressing should not only provide a relatively constant level of moisture at the wound but also absorb excess exudate. So modern dressings have been developed as an improvement for wound healing process. Their essential characteristic is to retain and create a moist environment around the wound to facilitate wound healing.

For the management of exudate, it requires appropriate wound dressing, which support the concept of moist wound healing. Studies suggest that wound fluid from acute wound may have a beneficial effect on wound healing while the chronic wound may inhibit healing.The application of dressings is influenced by the volume and viscosity of exudate within a wound (drew, 2007). The fluids in wounds also provide adequate nutrients for microbes to proliferate and cause infections, which can result in pain and discomfort to patients, thereby increasing treatment cost and nursing time. For these reasons, wound infection remains a challenge.

A typical wound dressing material should possess important abilities like the removal of exudates, protect the wound apart from having high porosity for air and vapour permeation and also act as a good barrier for protection of the wound from infection and dehydration. (Suganya *et al*., 2011). The prime function of wound dressing is to avoid strike through, to guard the wound site from infection and injuries.

The techniques used to fabricate wound dressings include braiding, knitting, weaving and non-woven in combination or alone. The construction of combined dressings is described as a mixture of different textile materials with different non-woven structures. Nonwovens are materials that are extensively used in the medical field and in protection against biological agents in other sectors. Nonwoven textiles aids as an excellent wound dressing material by means of its larger surface area and high porosity that serves as an open structure for the drainage of exudates and lessens the risk for secondary infection. Their use in this segment is based on a number of typical properties like lightness and softness, flexibility, absorption, filtering etc.

For the production of medical textiles in nonwoven, three main technologies are employed namely Hydroentanglement (Spunlace process), Spun bonding and Melt blown. Spunlace processing has a capability to produce a variety of surface and fabric patterns from many different web formation with fibers. The impaction of water jets will force the fibres onto and into the backing belt, giving the fiber web surface as same as the texture of the surface of the belt. If the backing belt has large holes, an apertured web is obtained; if it has very fine holes, then a non-apertured structure is obtained. This versatility associated with the configuration of the supporting belt provides the capability to produce a wide range of surface and structural features in a spunlace fabric. Hence Spunlace nonwoven has made itself to be fit in for wound dressing.

As a most suitable material for wound dressing various types of spunlace nonwoven fabric has been manufactured using different fiber composition. Later they are made into a dressing to identify the fluid handling capacity of fiber and fabric with different test parameters.

Therefore, to examine the fluid handling property the present study on “effect of different types of Spun lace nonwoven on wound pads exudates handling capacity characteristics” is aimed with the following objectives.

- To select raw material for the development of spunlace nonwoven with varied fiber composition
- To analyze the characteristics of developed spunlace nonwoven
- To develop nonwoven wound dressing pads
- To evaluate the characteristics of developed wound dressing pads

2. REVIEW OF LITERATURE

Review of literature pertaining to the study "effect of different types of spun lace nonwoven on wound pads exudates handling capacity characteristics" is discussed under the following headings.

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2.1 WOUND

A wound is defined as a break in the epithelial integrity of the tissue. This disruption can be deeper and involve sub epithelial tissues including dermis, fascia and muscle. They can be caused accidentally, intentionally or be a part of a disease process. The history of wound care has been evolved as a simple wound covers ranging from vinegar-soaked dressings, to topical antibiotics to topically applied growth factors (Rajendran, 2009). The skin is the largest and an important organ of the human body and has many different anatomical and physiological functions. The skin has three layers referred as epidermis, dermis and subcutaneous layer. The epidermis is the outermost layer of the skin and is composed of mostly dead cells associated with protein called keratin. Presence of keratin makes the outer layer waterproof and plays an important role for protection against the environment. Dermis is the middle layer of the skin primarily composed of collagen supports nerve fibres, lymph vessels, blood vessels, sweat glands and hair follicles. The subcutaneous layer act as a heat insulator which keeps our body warm and stabilizing our body temperature. Basically padding out the whole body working like a shock absorber. The wound is an injury, that takes place within the skin or any other external surface is torn, pierced, cut or broken with disruption of usual continuity of structures. They may be caused by physical, chemical, thermal, microbial or immunological insult to the tissue. They result in the loss of epithelial cells with or without the loss of underlying connective tissue (Raina *et al*., 2008).

2.1.1 CLASSIFICATION OF WOUND

Based on the duration of the time to heal, wounds are classified as "acute & chronic" wounds.

2.1.1.1 Acute wound

Acute wounds are usually tissue injuries that heal faster, with minimal scarring, within the expected time frame, usually 8-12 weeks. The primary causes of acute wounds include mechanical injuries due to external factors such as abrasions and tears which are caused by frictional contact between the skin and hard surfaces. Mechanical injuries also include penetrating wounds, caused by knives and gun shots and surgical wounds caused by surgical incisions. Another category of acute wounds include chemical injuries, which arise from a variety of sources such as radiation, electricity, corrosive chemicals and thermal sources (Percival, 2005).

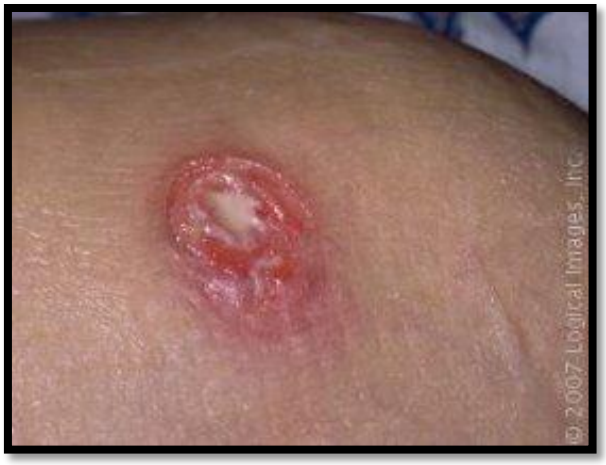

Figure 1

Acute wound

2.1.1.2 Chronic wound

Chronic wounds will fail to heal with in a time frame that heals slowly, where the healing process will exceed above 3 months (Harding et al., 2002). Kumar *et al* (2007) reported that nearly 6 million people suffer from chronic wounds worldwide. Some examples of chronic wound such as diabetes ulcer, pressure ulcer and malignancies. Other factors are persistent infections, poor primary treatment and other patient related factors (Moore et al., 2006).

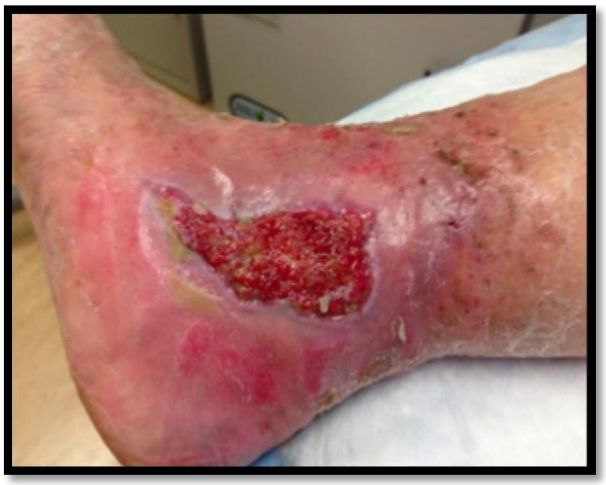

Figure 2
Chronic wound

2.1.1.3 Other Type of Classification

Wounds are also differentiated as open or closed wound types:

- **Open wounds** include incision or incised wounds, laceration, abrasions, punctured wounds and penetrating wounds.
- **Closed wounds** include contusions, haematoma and crush injuries.

2.1.2 WOUND HEALING AND STAGES OF HEALING

Wound healing is a compound process in which it undergoes four phase's haemostasis, inflammatory, proliferation and remodelling. The phases are overlapping and linear for acute wounds; whereas the chronic wounds can be found at different stages of the healing process and do not heal in an orderly manner (Li *et al*., 2007).

2.1.2.1 Haemostasis

Haemostasis occurs within a few minutes after a tissue is injured. The disruption of blood vessels and the resulting leakage of blood into the wound are followed by platelet activation and aggregation. This will then lead to the formation of a fibrin clot which causes the bleeding to stop and seals off the exposed tissue. Drying of the clot forms a scab that provides a temporary protection to the damaged skin in addition to serving as a provisional matrix for cell migration and as a source for cytokines and growth factors (Li *et al*., 2007; Heng, 2011; Korting *et al*., 2011).

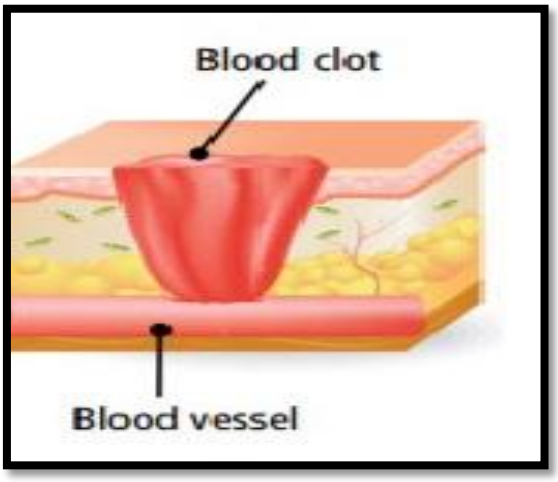

Figure 3
Haemostasis

2.1.2.2 Inflammatory/ Inflammation

The inflammatory reaction takes place soon after haemostasis and can last for more than 72 hours. This phase consists of attraction of neutrophils and monocytes from the circulating blood to the wounded area leading to cleansing and elimination of germs and debris. The infiltration of immune cells is a result from chemotactic signals from growth factors, epitopes of invading microorganisms, proteolysis of fibrin and other matrix components (Shaw and Martin, 2009; Heng, 2011; Korting *et al*., 2011).

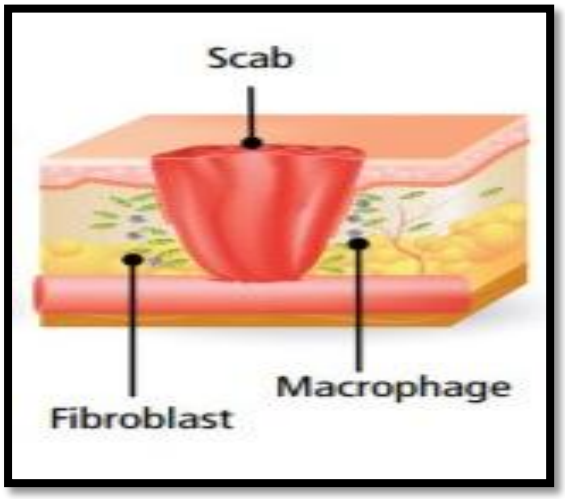

Figure 4
Inflammation

2.1.2.3 Proliferation

The proliferative phase of the wounded skin starts 4-5 days after injury. It consists of re-epithelization and wound contraction. Re-epithelization involves migration of keratinocytes into the wound, proliferation of keratinocytes, and regeneration of the basal cells that connects the epidermis with the dermis, and reconstitution of the dermis. The latter is carried out by the formation of new blood vessels, fibroblast proliferation and formation of the extracellular matrix such as collagen. At the macroscopic level, this phase of wound healing can be seen as an abundant formation of granulation tissue. (Korting *et al*., 2011).

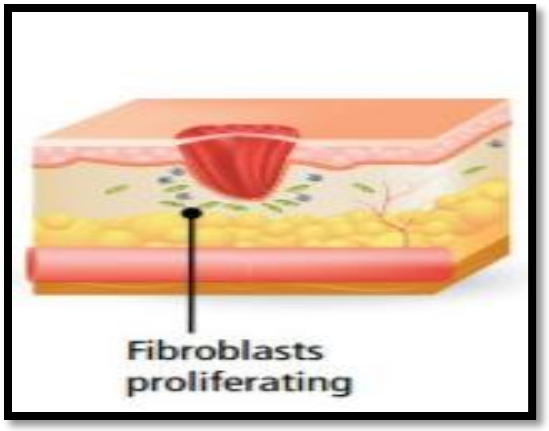

Figure 5
Proliferation

2.1.2.4 Remodeling

Remodeling phase of wound healing is intermediate between the formation of new cellular connective tissue and its degradation by proteases. This stage, which may continue for months, is characterised by modification of the structural integrity of the tissue with the aim of restoring normal architecture of the skin. Depending on the regulation of this maturation process the final result may either be a scar that is in distinguishable from the healthy skin, which is the goal, or scar tissue that elevates above the surrounding unwounded skin, indicating a deficient regulation of the process (Li *et al*., 2007; Shaw and Martin, 2009; Heng, 2011).

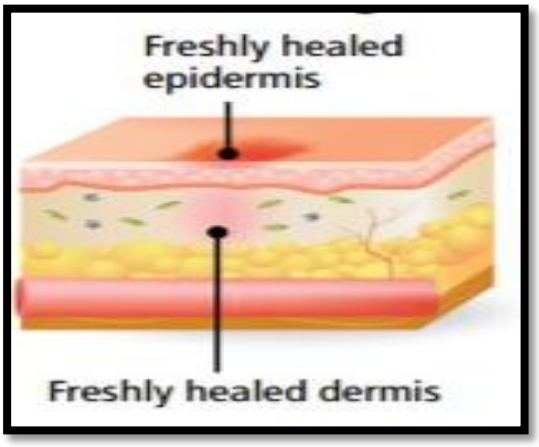

Figure 6
Remodeling

2.1.3 FACTORS AFFECTING WOUND HEALING

Wound healing is a most common process which leads to the restoration of tissue integrity. But in some cases wounds fail to heal and become complex medical problem which requires specialised care and treatment. Wound healing is dependent on the interaction of different cells, mediators and growth factors. The systemic and local factors are affecting wound healing process (Je et al., 2006)

2.1.3.1 SYSTEMIC FACTORS

2.1.3.1.1 Ageing

Healing in elderly is generally delayed but the final result is qualitatively similar in old people. There are many physiological changes associated with ageing which can lead to delayed healing. Reduced skin elasticity and collagen replacement influence healing. Reduced immunity and other chronic diseases can also affect the healing process (Jhones and Prince, 2001).

2.1.3.1.2 Nutritional status

Deficiency of various nutrients and vitamins can affect the wound healing process. Proteins are required for all the phases of wound healing and are particularly important for collagen synthesis. In protein deficiency states, cellular and humoral immune responses are blunted, fibroplasia and all aspects of matrix formation are delayed.

Glucose balance is essential for wound healing and it provides the energy required for cell function. The deficiency leads to suppression of collagen deposition in the wound. Deficiency of fatty acids can also impair healing.

2.1.3.1.3 Vitamins

Vitamin A deficiency has been associated with slowed re-epithelisation, decreased collagen synthesis and stability and an increased susceptibility to infection. Vitamin C (ascorbic acid) is an essential cofactor during collagen biosynthesis. In scurvy, the collagen formed is unhydroxylated, relatively unstable and subject to collagenolysis. Vitamin K deficiency results in a deficiency in the production of the clotting factors (factors II, VII, IX and X) that are vitamin K dependent resulting in bleeding diathesis, hematoma formation and secondary detrimental effects on wound healing. Iron is required to transport oxygen. Other minerals like zinc and copper are

important for enzyme systems and immune systems. Zinc deficiency contributes to disruption in granulation tissue formation.

2.1.3.1.4 Underlying diseases

Diabetes, arthritis, renal disease, heart disease, cancer, immune disorder, lung disease blood disorders and surgery affect the process of wound healing.

2.1.3.1.5 Medication

Anti-inflammatory, cytotoxic, immunosuppressive and anticoagulant drugs reduce healing rates by interrupting cell division or the clotting process.

2.1.3.2 LOCAL FACTORS

2.1.3.2.1 Infection

Infection is the most common cause for delayed wound healing. Bacteria delay wound healing by activating the alternative complement pathway and exaggerating and prolonging the inflammatory phase of wound healing. The bacteria, themselves produce toxins and proteases and compete for oxygen and nutrients, and this ultimately damages the cells (Vowden, 2002).

2.1.3.2.2 Tissue ischaemia

Local hypoxia is detrimental to cellular proliferation, resistance to infection and collagen production. This may be the result of foreign bodies, infection, suture material, or the presence of peripheral vascular disease.

2.1.3.2.3 Poor surgical technique

Proper tissue handling and closure with appropriate sutures is very important. Wound healing is affected if the tissues are devitalised, strangulated with sutures or improperly debrided.

2.1.3.2.4 Others

Formation of haematomas, presence of foreign bodies and mechanical pressure are some of the other local factors in the pathophysiology of delayed wound healing.

2.2 WOUND EXUDATES

Exudates are a protein rich fluid that has been slowly discharge from a cell or blood vessels. It is a key component which is secreted from inflammatory stages of healing. It is a liquid produced from wounds after hemostasis. Exudates maintain the wound bed moist, supply nutrients to the wound, allow migration and mitosis of epithelial cells and supply leukocytes to control bacterial infection. Studies suggest that wound fluid from acute wounds may have a beneficial effect on wound healing, whereas that of chronic wounds may inhibit healing. Any unexpected change in exudate characteristics may indicate a change in wound status and may indicate the presence of infection. It is generally characterised pale amber in color, but contamination by bacteria or fistula output may change this, giving a green (typically *Pseudomonas aeruginosa* infection), brown or black exudate and wound bed (Vowden, 2015).

A heavily exuding wound produces 5ml per $10cm^2$ per 24 hours. (Cowan T, 2014) Unmanaged high levels of exudate can cause peri wound damage (Bishop et al, 2003). The presence of excess exudates in the wound bed leads to many problems (Cooper 1999). If a wound bed is very dry, moisture needs to be added. Many patiens want their wound to dry out and do not understand that it is essential to have a moist wound environment for healing process (Bolton, 2007). Hence, present day wound dressings are focused on maintaining the moisture level of wound bed by the removal of excess exudates (Thomas, 1997).

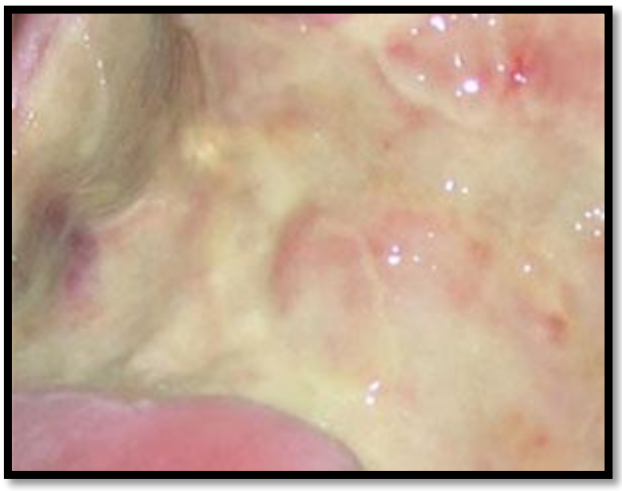

Figure 7

Wound exudates

2.3 WOUND MANAGEMENT

From very ancient times to present modern era, some suitable material has to be used to cover the wound in order to prevent any infection and to achieve effective healing of a wound (Zahedi *et al*., 2010). The effective wound dressing should able to management of wound exudates. The absorbency and permeability of dressing have an impact on its fluid handling capacity (Atkin, 2015). Successful wound management requires a flexible approach to the selection and use of products based upon an understanding of the healing process and knowledge of the properties of the various dressing available (Thomas, 2008). Moisture retaining dressings retain moisture or have low enough moisture vapour transmission rate (less than 35g/m^2/hour in partial thickness wounds), permitting moist wound healing (Wiegand et al, 2015).

The goal of effective wound management is to remove excess moisture, debris and chemicals from the wound surface while maintaining the ideal moisture balance to allow cells to migrate and ultimately heal the wound (Vowden, 2002). If exudate is not managed, strikethrough of the dressing occurs, leading to an increased risk of infection, although it must be remembered that an increase in wound exudate may be an indication of infection. (Dowsett, 2015).

2.3.1 Acute Wound Management

An important concern in the management of acute wounds is that the handling and treatment of tissue must be as a traumatic (i.e., non-traumatic) as possible. In addition to the suitable management of wound pain, wound edges must be closed using appropriate primary closures like adhesives, strips, sutures and staples to minimize the risk of infection and scar formation. Time required for the removal of primary closures depends on the location and extent of the incision. Leaving sutures in too long contributes to scarring and infection. Tissue reconstruction is necessary and beneficial in wounds with extensive tissue damage (Vowden and Vowden, 2009).

2.3.2 Chronic Wound Management

The care and management of chronic wounds require proper assessment and accurate treatment strategies to ensure appropriate supply of oxygen and nutrition in order to address the pathological conditions including ischemia, bacterial load, and imbalance of proteases involve at the wound bed. Various approaches which are commonly selected in the treatment of chronic

wounds includes debridement, irrigation, moist wound healing, oxygenation, removing mechanical stress, and adding growth factors or cells or other materials to release that contributes for wound healing (white and cutting, 2006).

2.4 WOUND DRESSING

The selection of dressings should be a part of wound healing and should prevent further damage to the wound. An ideal dressing should maintain a moist environment at the wound interface and act as a barrier to micro-organisms. An ideal dressing not only maintains a moist environment but also allows gaseous exchange and provides thermal insulation to maintain the optimum wound core temperature. Dressing vary in the way they deal with exudate. Unlike gauze or cotton wool products, that tend to lock away some of the exudate with the fibers or particles of the dressing (Thomas, 2010).

2.4.1 IMPORTANCE OF WOUND DRESSING

The dressing should not be simply mopping up. It should be able to manage the exudate in such a way as to enhance the wound environment. Understanding the exudate handling properties of wound dressing and the recommended wear time is essential. Skin reactions, such as sensitivity and contact dermatitis, are often caused by inappropriate dressing selection and insufficient dressing changes (Cameron, 2001). Dressing that rapidly absorb exudate and hold the moisture within the dressing thus holding harmful chronic wound exudate away from the surrounding skin are most effective at preventing maceration. Ideally, they should also be easy to remove and be cost effective (White and cutting, 2006).

Dressing is a component that uptake the wound fluids (Thomas, 2009). Wound dressings form an important segment of wound management products. Today, effective wound dressing requires not only protecting the wound from its surroundings but also promoting healing by providing an optimum microenvironment for healing, removing any excess wound exudate, and allowing continuous tissue reconstruction (shyu, 2001). In earlier days, the dressings used for healing are bandages and gauze with varying degrees of absorption. Bioactivity appears to be the way forward in advanced wound dressings for removing excess exudate by maintaining moist wound site, to promote wound healing and for preventing infection and cellular interactions (Persin, et al., 2014, Weller and Sussman, 2006). An ideal wound dressing need to promote fast

healing at minimum cost, with negligible trouble to the patient. Accurate assessment and diagnosis of wound aetiology combined with comprehensive understanding of the features of modern materials will enable healing and maximise patient comfort (Jhones and Prince, 2001).

2.4.2 PROPERTIES OF WOUND DRESSING

An ideal wound dressing should promote rapid healing by maintaining a moist environment, absorbing exudates without drying out the wound surface, protecting from microbial invasion, preventing infection, and allowing for gaseous exchange. It should also be easy to apply, be adhesive enough to achieve adequate residence time, but easy to remove without leading to discomfort or trauma, with less frequent changes (Seaman, 2002; Brett, 2006). Wound fluid is initially taken up by the absorbent component of the dressing. The ideal wound dressing should not contain particulate contaminants that may be left in the wound and lead to infection (Vermeulen *et al*., 2005). A wound dressing should not be toxic or allergenic. No single dressing fulfils all of the preferences mentioned above, and the choice of dressing depends on the wound type and the state of the tissue, which can vary at different stages of the healing process. The activity level and personal needs of the patient should also be considered in the properties of most suitable dressing (Jayakumar *et al*., 2011).

2.4.3 TYPES OF WOUND DRESSING

Wound dressings are classified into traditional and modern. Cotton wool, natural or synthetic bandages and gauze materials are referred as a traditional wound dressing. While modern wound dressing includes foam dressing, alginate dressing, hydrogels, hydrocolloids, semi-permeable adhesive film dressing, composites and biological dressing (Dinah & Adhikari 2006).

In other way wound dressings can be divided as primary and secondary dressing, primary dressings are which comes in contact with the wound surface, secondary dressings are those which cover the primary dressing. Island dressings are made with an absorbent layer in the centre surrounded by an adhesive part (Boateng et al., 2008).

2.4.3.1 TRADITIONAL DRESSINGS

Bandages and gauze are made of cotton or other materials and are termed as traditional dressings (Hoekstra et al, 2002). These are dry dressings and will not create a moist environment on the wound surface. Traditional dressings are used as primary or secondary dressings based on their application and function (Jones, 2006). For packing open wounds, sterile gauze pads are used to absorb fluid and exudates. These gauze dressings should often be changed based on the amount of exudates to avoid maceration (Falabella, 2006).

2.4.3.2 MODERN WOUND DRESSINGS

Main characteristic of maintaining the moisture level is the foremost advantage of modern dressings. They also become a part of drug delivery for the healing of the wound (Hampton, 1999).

2.4.3.2.1 Hydrocolloid Dressings

Due to the gel forming nature, hydrocolloids are widely used for modern dressings with inherent wound healing properties. Gelatin, pectin, and carboxy methyl cellulose are the gel forming agents and can be formulated as films and sheets (Schaller et al, 2004). They are used in healing of moderately exuding wounds like pressure sores, traumatic injuries, and minor burns. Due to their absorbent nature, their water vapor permeability also gets increased while forming gels (Thomas & Loveless 1997).

2.4.3.2.2 Alginate Dressings

Alginate dressings are prepared in the form of foams or fibrous sheets. Due to their higher absorbency, alginate forms gels when it is in contact with exudates. The calcium ions present forms a cross linked polymeric gel when in contact with fluid. This characteristic feature makes alginate dressing minimize bacterial contamination (Doyle et al, 1996). The calcium ions released, also aids in clotting mechanism. When compared with hydrocolloid dressings, alginate dressings last longer on the wound surface (Thomas 2000). Alginate dressings can be used from Moderate to heavily exuding wounds. These dressings are not suitable for dry wounds which is covered with necrotic tissue (Thomas et al 2000).

2.4.3.2.3 Hydrogel Dressings

Hydrogels are hydrophilic materials, which is able to swell. They are prepared from synthetic polymers. The form of the hydrogel dressings may be gel, film or solid sheet (Moody, 2006; Luo et al, 2000). Significant amount of water is entrapped or absorbed by the hydrogels and retained. Hydrogel dressings are suitable for light to moderately exuding wounds. They can be used as primary and secondary wound dressings (Ueno et al 2001).

2.4.3.2.4 Semi-Permeable Adhesive Film Dressings

These semi-permeable dressings were initially prepared from nylon derivatives with an adhesive polyethylene support. Due to nylon, the ability of absorbing water is limited. They tend to wrinkle and become difficult to apply on the wound site. They are more flexibile, good conformity, and are transparent. But the usage of material will differ on extensibility, water vapor permeability and conformability (Boateng et al, 2008).

2.4.3.2.5 Film Dressings

Films are semi-occlusive dressings, which can be used directly on the wound or used as a secondary dressing. Film dressings can be used for moderately exuding wounds to avoid fluid trapping (Fonder et al 2008).

2.4.3.2.6 Foam Dressings

They provide thermal insulation and maintain a moist environment. Foam dressings are highly absorbent and have a high moisture vapor transmission rate. The absorbency of foam dressings can be controlled by foam properties. They are suitable for light to moderately exuding wounds (Boateng et al 2008).

2.4.3.2.7 Biological Dressings

Biological dressings are prepared from biomaterials and also called as bioactive dressings. They are biodegradable and help in new tissue formation. These dressings can be incorporated with antimicrobial compounds and growth factors to be delivered at the wound site (Khan and Davies 2006). Chitosan, collagen and hyaluronic acid are also used as biological agent for the delivery of drugs to the wound site (Cho et al 2002).

2.4.4 CHARACTERISATION OF WOUND DRESSINGS

The performance of wound dressings is influenced by the physical, mechanical and biological properties of the dressings. The standard test methods developed by US and British pharmacopoeia (BP), British standards (BS) and American Standards for Testing and Materials (ASTM) are used as the evaluating criteria for wound dressings (Khan & Peh 2003and Gatti et al 2004).

2.4.4.1 PHYSICAL TESTING

The standard tests include moisture vapor transmission rate, fluid handling properties, fluid affinity, gelling properties, tensile strength, and elongation and water uptake. (Mangala et al 2003).

2.4.4.1.1 FLUID HANDLING TEST

The effective management of the moisture content of a wound and the surrounding skin is the most important requirements of any dressing. In the case of exudating wounds, this implies the removal of excess wound fluid, but in dry or lightly exuding wounds, the dressing may be required to conserve moisture in order to maintain the optimum state of hydration. However, most permeable products are unable to cope with the volume of fluid that is produced by heavily exuding leg ulcers, burns or malignant wounds. In such situations, products that have the ability to absorb or otherwise retain quantities of liquid are required, with a significant degree of moisture vapour permeability. These two values determine the ability of a dressing to cope with wound exudate and are described as its fluid handling capacity (FHC).

2.4.4.1.1.1 Free Swell Absorbency

The standard test described in BS EN 13726-1, measures the uptake of fluid by f dressings made from fibre presented either in sheet or rope form. The dressing is placed in a Petri dish together with a quantity of test solution equivalent to 40 times the weight of the test sample, and held for 30 min at 37 °C after which it is gently removed from the dish, allowed to drain for 30 s and reweighed. The absorbency is then expressed as the mass of solution retained per 100 cm^2 (for sheet dressings) or per gram of sample for cavity dressings. In the presence of sodium ions, fibres absorb fluid and swell, sometimes taking on a gel-like appearance. The degree of

swelling and dispersion is determined by the chemical structure, ionic content and method of preparation of the dressing. These properties are quite important as they determine how the dressing will perform when introduced into a wound.

2.4.4.1.1.2 Fluid Handling Capacity

The test, described within BS EN 13726-1, is the amount of test fluid both retained and transpired by dressings, which incorporate an integral waterproof backing layer. A piece of dressing is cut to shape and clamped between the annular ring and one of the flanges. The cylinder together with all the associated parts is then weighed. Approximately 20 ml of test fluid is added to the cup and the plate clamped in position. The cup is then weighed again before being placed in an incubator with the temperature (37 ± 1) °C and relative humidity <20% throughout the test.

After a period (usually 24 h) the cylinder is reweighed, the plate is removed and the excess fluid is allowed to escape, then the cylinder is reweighed once again. From these weightings, it is possible to calculate the amount of fluid lost through the back of the dressing by evaporation during the period of test, and the weight of fluid retained within its structure. The sum of these two values represents the Fluid Handling Capacity of the dressing.

2.4.4.1.2 Moisture vapour transmission rate (MVTR)

Here same apparatus described in BS EN 13726-1 may be used in a similar way with less complicated fashion, to determine the MVTR for dressings. This method is described in BS EN 13726-2. The amount of moisture evaporation from the surface of a dressing can be quantified as the moisture vapour transmission rate (MVTR). In wounds with a high amount of exudate the dressing material will need a high absorptive capacity to remove the excessive fluid. Wound with low amount of exudate can be managed with dressing that have a high moisture vapour transpiration rate (MVTR), which allows the fluid to evaporate from the wound site. Users of this type of biomaterial need to ensure moisture vapour transmission is not blocked by the use of tapes and additional dressing materials over the primary dressing (jones and Milton, 2000).

2.4.4.1.3 Fluid-affinity test

The standard method has been described in BS EN 13726-1. Some dressings, both in sheet and amorphous form, have the ability to absorb or donate liquid according to the condition of the underlying tissue. This means that they can absorb fluid from a heavily exuding wound or donate moisture to dry for healing. Test systems are therefore required which can be used to assess both these properties. The transfer of liquid to or from the test sample to the standard gels is measured by recording any change in weight of the sample.

2.4.4.2 Low-adherence test

The results of international survey, identified that pain and trauma were ranked as the most important factors to consider when changing dressings. The pain was most commonly associated with dressings drying out or adhering to the wound bed, factors that were also considered to be responsible for wound trauma. It is generally believed that there are two mechanisms of adherence. The first is the inherent 'stickness' of serum which acts like a simple adhesive that forms a bond between two opposing surfaces. The second mechanism is a little more complex, involving the penetration into the dressing of serous fluid containing cellular debris which dries to form a solid 'scab' on the wound surface.

2.4.4.3 Conformability test

Dressings applied around joints or to other areas of tissue that are subject for movement without causing excess pressure, or in the case of adhesive products, shearing forces that can cause skin trauma. A test designed to assess the extensibility and permanent set conformability of primary wound dressings by measuring its extensibility and permanent set is described in BS EN 13726-4. In this test, strips of dressing 25 mm wide with an effective test length of 100 mm are extended by 20% in a constant rate of traverse machine at 300 mm min^{-1}. The maximum load is recorded and the sample is held in this position for 1 min. It is then allowed to relax for 300 s before being remeasured. In this test, the conformability of a dressing is considered to be inversely proportional to the pressure required to deform it by a predetermined amount and is represented by the mean inflation pressure of the samples examined.

2.4.4.4 Microbiological tests - Bacterial barrier properties

This test is currently being evaluated by the industry before being formally proposed as a new European Standard. Wounds of all types represent a potential source of cross-infection, particularly if they are infected with antibiotic resistant organisms. The ability of a bacterium to pass through a dressing is determined by the presence of a liquid pathway. A sterile dressing is aseptically clamped between two sterile flanged hemispheres (closures of reactions vessels are typically used) such that the dressing is maintained in the vertical plain. A microbiological liquid nutrient medium is introduced into both chambers one side of which contains a heavy inoculum of a suitable test organism. If no growth is visible, the dressing is considered to represent an effective bacterial barrier but, if growth is detected, samples are plated out to confirm that it is the test organism in aseptic technique.

2.4.4.5 Biological tests

Because dressings come into intimate contact with damaged tissue, blood or body fluids, it is important to ensure that they are free from any agents that can adversely affect wound healing or otherwise cause an adverse reaction within the wound. The standard approach to testing medical devices is described in BS EN ISO 10993.

2.4.4.5.1 Test for irritation and sensitisation

This part of the standard describes a technique in which extracts of the dressing are injected subcutaneously into multiple sites on the backs of rabbits following which the injection sites are examined visually for evidence of irritation immediately and after 24, 48 and 72 hours.

2.4.4.6 Odour control tests

Certain types of wounds such as pressure ulcers, leg ulcers and fungating (cancerous) lesions produce noxious odours which, even in moderate cases, can cause significant distress or embarrassment to a patient and their relatives. The smell from a wound is caused by a cocktail of volatile agents produced by anaerobic bacteria. Organisms frequently isolated from malodorous wounds include anaerobes such as *Bacteroides* and numerous aerobic bacteria including *Pseudomona*. A more objective test system that could be used to compare the ability of different dressings to prevent the passage of a volatile amine when applied to a wound model under

simulated ‘in-use’ conditions was devised by SMTL. The test solution, consisting of Solution A to which is added 2% diethylamine and 10% newborn bovine serum, is applied to the dressing through the perforated plate at a rate of 30 ml h−1 by means of a syringe pump. The air in the perspex chamber is constantly monitored and the measured values are recorded electronically using a datalogger.

2.5 FIBRES USED FOR WOUND DRESSINGS

The application of textile materials to promote healing of wounds has a long tradition. (Pivec et al.,2014). The features and characteristics of fibres are directly associated to fabric performance and care (Kaplan, 2002). A number of polymeric materials are used as films, fibers and other structures for developing wound-dressing products. Some of the primary materials employed are cotton, rayon, polyester, acrylic, polyurethan, bamboo and viscose. (Gupta and Edwards, 2009). Polyester, and regenerated cellulosic fibres were used as absorbent pads (Karthik and Wasif, 2014). The high absorption capacity as well as the wettability of cellulosic fibre makes it an ideal material for making wound dressings in the form of woven or nonwoven textiles (Persin et al., 2014).

2.5.1 Cotton

Historically cotton fibers were used highly in construction of dressings, absorbent pads, and bandages, which still stands for a significant of wound-care products in the world. The most commonly used cotton in wound products is short fibers (<2.5 cm). The cross-section of cotton is kidney bean shaped, but it becomes round when swollen with aqueous fluids. The moisture regain of cotton is about 8%, but when it is soaked it can take up to about 30% water and swell significantly. One of the unique characteristic of cotton is that it becomes stronger when it is wet. The structure can be chemically modified to incorporate additional hydrophilic groups to enhance the fiber’s absorptive properties. So cotton fiber is more preferable for wound dressing (Edwards, 2009).

2.5.2 Rayon

The fiber is chemically similar to cotton but differ in its physical structure. These differences make rayon relatively weaker and more extensible, but more absorbent than cotton.

The moisture regain of rayon is 14% but when it is soaked, it can swell and absorb almost 70% by weight water. The fiber, however becomes significantly weaker when wet and therefore requires care when used directly on open wounds. The major applications of the fiber are disposable absorbent pads, sponges, and sanitary napkins.

2.5.3 Polyester

Polyester is one of the most versatile fibers. They are used in many categories of textile products. But in medical products polyester is in extensive usage. Because of the lack of polar groups, the fiber has a low moisture regain of 0.4% which is under normal conditions. This makes the material largely hydrophobic. Polyester fibre is characterized as a strong, soft hand and quick drying fibre. It has a better conductor of heat. They resist mildew and it is also unaffected by moths, carpet beetles, or other insects. However, polyesters fabrics may exhibit other advantages over natural fabrics, such as improved wrinkle resistance. It is also frequently used for combining with cotton and rayon in developing needled and spunlaced non-wovens for dressings (Singh, 2008).

2.5.4 Acrylic

They are highly polar and lead to extensive bonding between chains. The moisture regain is 2% which has limited interaction with aqueous fluids. A major attribute of this fiber suits for use in dressings. It is naturally high resistance to colonization of micro-organisms.

2.5.5 Viscose

Viscose is a regenerated cellulose fiber. The raw material is obtained from a special variety of wood (spruce). It is a very versatile fiber and has same comfort properties like natural fiber. Viscose absorbs more moisture than cotton. Moisture content for viscose rayon is 13% (Kothari, 2000). It imitates the feel and texture of silk, wool, cotton and linen. It has the characteristics like soft, smooth, cool, low elastic recovery and highly absorbent, but do not insulate body heat (opines Cook, 2005).

2.5.6 Bamboo

Bamboo fibre is a regenerated cellulose fiber, which is produced from raw materials of bamboo pulp. Bamboo fiber can be softer even than silk fiber. It has a basic round surface which makes it very smooth and to sit perfectly next to the skin. It's organic and natural smooth properties are non-irritating to the skin, making ideal for people with skin sensitive's or other allergies. Bamboo fiber absorbs and evaporates sweat very quickly. Its ultimate breathability keeps the wearer comfortable and dry for a very longer period. It is 3-4 times more absorbent than cotton. Bamboo fibre has natural UV resistant properties (opine Rathod and Kolhatkar 2010). The cross section of the bamboo fiber is filled with various micro-gaps and micro-holes leading to much better moisture absorption and ventilation. Bamboo is naturally antibacterial, antifungal and anti-static. Bamboo fabrics are healthier, germ free and odour free. Bamboo has also wide prospects in the field of hygiene material such as sanitary napkins, bandages, wound dressing, surgical cloth and masks. (Sinha and Malik, 2011).

2.6 FABRICS USED FOR WOUND DRESSINGS

A dressing is an aid applied to a wound to stimulate fast healing and to avoid further damage. The wound dressings used in textiles includes fibres, yarns, filaments, knitted, crochet, braided, various woven structures and nonwoven materials. (Mohapatra, et al., 2014).

2.6.1 Woven fabrics

Here gauze fabrics are based on woven structures. The simple plain weave has been used in woven fabrics for wound management applications Woven fabrics are relatively inextensible but dimensionally very stable structures with porosity that can be varied from nearly zero value to very high value (gauze, cheese cloth). A major problem with the woven fabric is the tendency of threads to unravel at the cut edge. (Gupta et al., 2009)

2.6.2 Knitted fabrics

The knitted nets and bandages can be draped more effectively than woven materials over areas that require three-dimensional conformability. The knitted fabrics are more flexible, compliant and conformable than the woven fabrics, and they do not unravel easily. The knitted

fabrics have high porosity. One of the primary applications of knitted structures in wound care is in compression hosiery used for treatment of venous stasis.

2.6.3 Nonwoven fabrics

The versatility of nonwovens to be engineered to offer unique and extraordinary properties makes it so efficient for healthcare end uses (Walker, 2001). The specific features of non-woven fabric like high porosity, ventilation, large surface area, absence of dust, and easy processing makes it extensively utilised for medical dressings (Liu, et al., 2009). The characteristics like absorbency, filtering efficiency, sterility, resilience, cushioning, strength, elasticity, flame retardancy, liquid repellence and bacterial barrier efficiency can be incorporated in nonwoven fabric according to the end use (Horrocks, 2000).

2.6.3.1 ADVANTAGES OF NONWOVENS

Protection, cost, and comfort are key drivers for the continued usage of nonwovens in medical textiles field and growth in market. Traditional fabric and other structures are now replaced by nonwovens. Nonwovens can be prepared from natural materials like cotton, wood pulp, paper, and linen, or man-made materials such as polypropylene, polyester, polytetrafluoroethylene (PTFE) and polyimide. The synthetic nonwovens are also effective, and the parameters like weight, thickness and porosity can be easily controlled along with better sterilization (Gupta 2010). Lightweight, flexible and soft nonwovens are used for moist wound dressings. They also offer precise fluid retention porosity, absorbency control, low shedding performance, and low dust. Thus, enhancement in absorption and retention of fluid level allows longer use and less frequent changing of dressing. By inherent properties, these nonwovens also offer antimicrobial and anti-inflammatory properties (Liu & Huang 2009).

2.6.3.2 NONWOVEN IN WOUND DRESSING

Nonwoven fabrics are widely used in filtration, geotextiles, and medicine and hygiene applications. The use of nonwoven fabrics in medical textile field can be classified broadly in three groups; viz. wound pad and adhesive plaster, wound dressing and operation theater clothing (Rakshit et al 1994). A nonwoven fabric is a typical fabric-like material which is made

directly from long fibres, bonded together by chemical, mechanical (needle punching or hydroentanglement), thermal bonding or solvent treatment.

Nonwoven is emerging segment in textiles which play a significant role in the medical sector. Nonwoven has got successful name for single use articles which require less sterilization and it is one of the reasons behind that nonwoven are risk-free from infections. The elevated manufacturing introduce nonwovens in all areas of the medical field, especially in the development of new wound dressings. Medical nonwovens are used as personal healthcare and hygiene products (masks, wipes, bedding, and surgical gowns), non-implantable medical dressings (wound care bandages, dressings, and surgical drapes) and implantable structures (tissue structures, orthopedic structures and sutures). The structure of nonwoven fabrics are similar to the structure of collagen and nonwovens also have controllable wound exudates absorbing ability, ideal thermal insulation and free from chemical detergents.

Nonwovens have a therapeutic effect in moist wound dressings, when it is used for highly exuding wounds. The dressings maintain the suitable moisture conditions around the wound surface. Hence, nowadays most of the dressings are used with a covering pad of nonwoven materials. The main focus of usage of nonwovens is due to its absorbing and retaining wound fluid (Huang et al 2010).

The cost of nonwoven is comparatively cheaper than the commercial fabric. (Karpagam and Manonmani, 2015). The main feature of nonwoven is it is used for backings and as wound pads in a wound dressing. The particular advantage offered by the material is they are easy to process, permeable to air, non-adherent to wounds and highly absorbent properties. The medical products for wound care are based on nonwoven material that are put in both post-operative wound care and in treating minor injuries (Sakthivel *et al.*, 2010).

2.6.3.3 SPUN LACE NON-WOVEN

Spunlace nonwoven has made itself to be fit in for wound dressing. From the last decades, spunlace nonwoven dressing is replacing the traditional wound dressing because of its functional advantages, physical characteristics and cost effectiveness (Chellamani *et al.*, 2013).

Generally, three techniques like spun bonding, melt blown and hydro entanglement were used to fabricate non-woven textile meant for medical products. Spun lace non-woven is a

premier one among the other techniques because of its high performance, high absorption capacity and economical (Chellamani, et al., 2013). Spun lace non-woven can bring out a fabric with brilliant strength, lint free, bulk and good absorbency which takes the superior choice of hygiene and medical textile application. The mechanical entanglement of web that loose staple fibres for their coherence by means of water jet under high pressure of a porous belt or moving perforated screen to form non-woven fabric is called hydro entanglement (Patel and Bhrambhatt, 2011). Spun lacing, hydraulic entanglement and water jet needling are identical terms defining the process of hydro entanglement. Non-woven fabrics manufactured by this method are having softness and good drape ability (Huang and Gao, 2004)

3. EXPERIMENTAL PROCEDURE

Experimental procedure pertaining to the study "effect of different types of spun lace nonwoven on wound pads exudates handling capacity characteristics" is discussed under the following headings.

3.1 Selection of fibers

3.2 Selection of fabrics

3.3 Development of Spunlace nonwoven fabric

3.3.1 Web formation

3.3.2 Web entanglement

3.3.3 Dewatering

3.3.4 Drying and winding

3.4 Chemical testing on Spunlace nonwoven

3.4.1 Acidity/ Alkalinity

3.4.2 Surface activity substances

3.4.3 Water soluble substances

3.4.4 Ether soluble substances

3.5 Overall liquid transport characteristic of developed Spunlace nonwoven

3.6 Development of nonwoven wound dressing pad

3.7 Preparation of wound exudates

3.8 Physical testing of developed nonwoven dressing pad

3.8.1 Free swell absorptive capacity

3.8.1.1 Method I

3.8.1.2 Method II

3.8.2 Strike through time

3.8.3 Time of absorbency

3.8.4 Surface dryness

3.8.5 Moisture vapour transmission rate (MVTR)

3.1 SELECTION OF FIBERS

The important qualities required for textile fibers to be used in medical textiles are moisture and liquid aBsorption, antistatic behaviour, highly porous and mechanical stability. Polyester and regenerated fibers satisfies all these requirements (Rajesh, 2006, Chinta and Veena, 2013). They are comparatively low-cost and mostly used for constructing non-woven fabrics. It is recommended for versatile medical applications where absorbency and sterilisation are important. Therefore polyester and viscose has been selected for this study.

3.2 SELECTION OF FABRICS

Nonwovens are heart of medical textiles that were used chiefly in disposable and health care sectors (Chellamani et al., 2013). Its high porosity and larger surface area provide an open structure for handling of exudates and reduces the risk of secondary infection. The absence of dust and easy processing of non-woven fabric serves as an excellent material for wound dressing application (Liu et al., 2008). Chiefly three technologies such as hydro entanglement, spun bonding and melt blown are used for the fabrication of non-woven medical textiles (Chellamani et al., 2010).

Spunlace non-woven fabrics hold a brilliant place in medical textiles. The porous structure of the fabric makes skin breath freely, which reduces wound infection. The high absorption capability along with safety and comfort makes the fabric user friendly. Hence, spun lace non-woven fabric was selected for the study as a base material.

3.3 DEVELOPMENT OF SPUN LACE NONWOVEN FABRIC

Spunlacing is a process of entangling a web of loose fibers on a patterned screen to form a sheet arrangement by subjecting the fibers to several rows of fine high-pressure jets of water. The steps involved in the production of spunlace nonwoven fabric includes:

a) Precursor web formation

b) Web entanglement through water jet application

c) Dewatering

d) Web drying & Winding

3.3.1 Web Formation

The fibers which were supplied in dense press-packed bales has been opened out and the tuft size of fibers has been reduced prior to carding using the opening line. The opening line used for the production of spunlace nonwoven was shown in Figure 8 has the following sequence of machinery.

a) Bale breaker

b) Hopper feeder

c) 6 lag kirschner beater

Opened material from 6 lag kirschner beater was fed to the roller clearer card through a chute feeding system.

Figure 8
Opening line

Figure 9
Roller clearer card

Roller clearer cards have been employed for fiber individualization was shown in Figure 9. This card has a central cylinder that is usually the largest roller. Smaller satellite rollers, called workers and strippers, which normally operate in pairs, are situated around the cylinder and they carry out the basic function of working and stripping. A simple roller clearer card configuration was shown in Figure 10

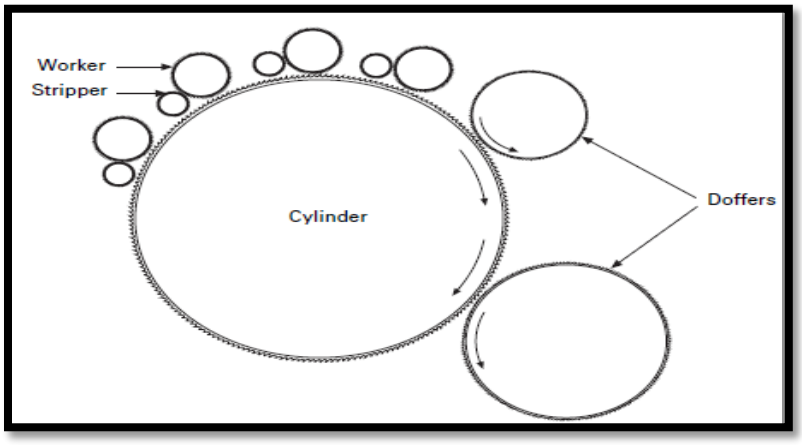

Figure 10

Roller clearer card configurations

Figure 11

Horizontal Cross lapper

A cross-lapper is a continuous web transfer machine that normally follows a roller clearer card as part of an integrated web formation system. The web was layered from side to side onto a lower conveyor, which runs perpendicular to the in-feed web to form a diagonally stratified batt, wadding or fleece. The ratio of the web in-feed speed to the output speed determines the lay down angle and the linear production speed is a function of both lay down width and the number of layers.

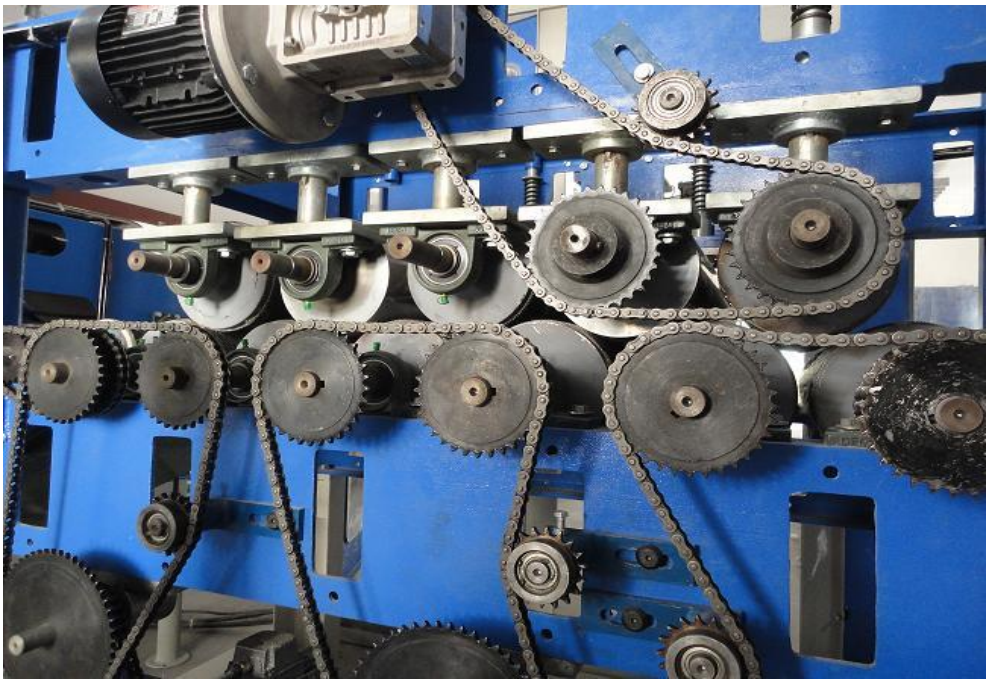

Figure 12

Drafting unit in a web drafter

After the formation of cross-laid web from the cross lapper unit, subsequently it was passed through web drafter to increase the fiber orientation in the machine direction. A web drafter consists of five over six roller drafting units, the surface speed of each set of rollers, increase from input to output to control the draft in between 1.5 -2.0.

3.3.2 Web Entanglement

The formed web was first compressed and prewetted to eliminate air pockets and then water-needled by passing through a series of water jets (injectors). The water pressure applied on the web increased from the first to the last water injectors. High Pressures of the order of 2200 psi (pounds per square inch) was used to direct the water jets onto the web.

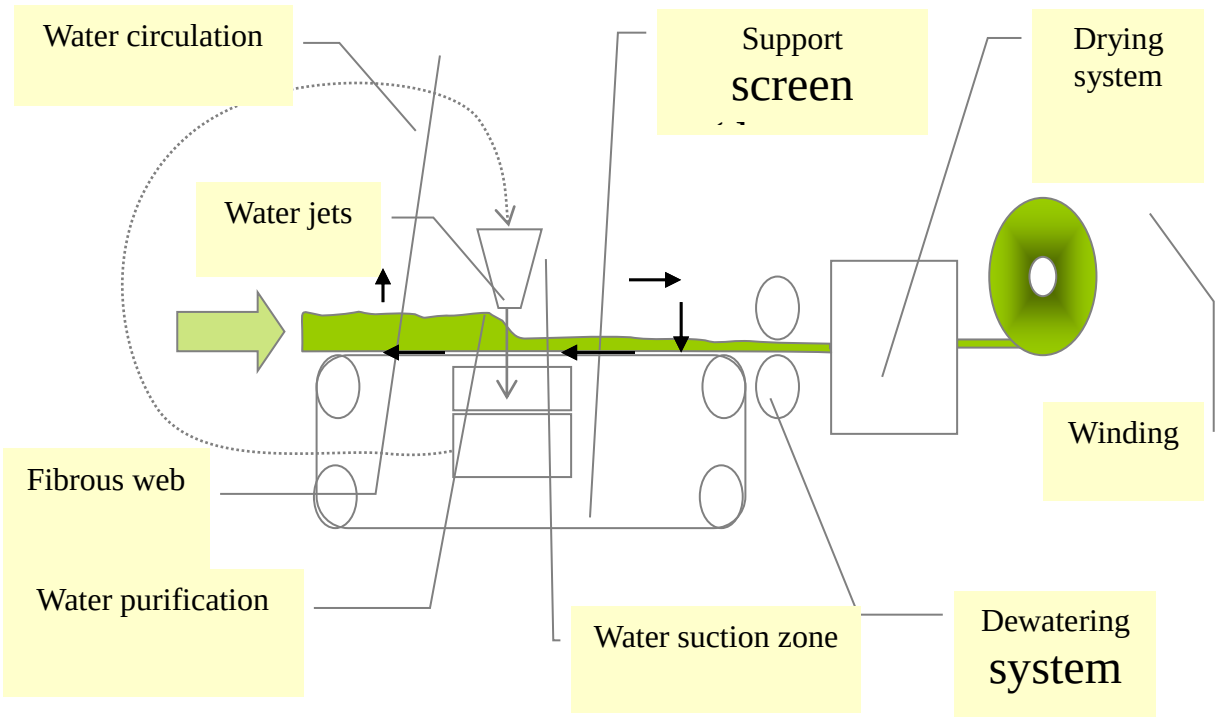

Figure 13

Spunlace process

Injector hole diameters are 100mm and the holes are arranged in rows with 3 mm spacing, with one row containing 40 holes per 25 mm. The impinging of the water jets on the web caused the entanglement of fibers. The jets exhaust most of the kinetic energy primarily in rearranging fibers within the web and, secondly, in rebounding against the substrates, dissipating energy to the fibers. The hydroentanglement was applied on both sides of the fibrous web in a step-wise manner. The first entanglement roll acts on the first side a number of times in order to impart to the web the desired amount of bonding and strength. The web then passed over a second entanglement roll in a reverse direction in order to treat and, thereby, consolidate the

other side of the spunlace nonwoven fabric. The fibrous web, which was subjected to water jet application, was supported by a support screen in the spunlace machine as shown in Figure 13 in its passage to the drying and winding section.

3.3.3 Dewatering

The hydroentangled spunlace nonwoven product is then passed through a dewatering system as shown in Figure 13 where excess water in the hydroentangled product was removed.

3.3.4 Drying and Winding

Figure 14

Spunlace drying & winding unit

Once the hydroentanglement spunlace nonwoven process (formation of spunlace) was over, the material that came out of the spunlace unit was wet. So spunlace nonwoven was dried and this was done using thermic fluid as the heating medium in the spunlace drying unit. After drying, the spunlace nonwoven material was wound on a beam.

Following the above given manufacturing process 6 different types of spunlace nonwoven fabric was developed for the present study which is mentioned in Table 1

TABLE I

Developed Spunlace Nonwoven

NONWOVEN SAMPLE	FIBERS USED	BLEND RATIO %	GSM
NWS 1	Polyester	100	90
NWS 2	Viscose	100	100
NWS 3	Viscose	100	70
NWS 4	Polyester/Viscose	30/70	90
NWS 5	Polyester/Viscose	44/56	100
NWS 6	Polyester/Viscose	35/65	70

3.4 CHEMICAL TESTING OF SPUNLACE NONWOVEN

The following tests were carried out to assess the presence of chemicals in the spunlace nonwoven fabric.

3.4.1 Acidity/alkalinity

Sample (15g) was taken in a suitable vessel and 150 ml of water was added. The vessel was allowed to macerate for 2 hours. Then the solution is poured and the liquid is squeezed carefully from the sample. 25ml of test solution were taken and 0.1 ml of phenolphthalein is added and another 25ml of test solution is added to 0.05ml of methyl orange solution. Presence of acidity/alkalinity was confirmed by appearance of pink color.

3.4.2 Surface activity substances

Sample (15g) was taken in a suitable vessel and 150 ml of water was added. The vessel was allowed to macerate for 2hours. Then the solution is poured and the liquid is squeezed

carefully from the sample. 25ml of test solution were poured into ground glass stopper cylinder. Vigorous shaking has been given continuously for 30sec. Examined after 5min and presence of foam has been noted in mm.

3.4.3 Water soluble substances

500ml of water is added to 5g of sample and allowed to boil for 30min. The water loss by evaporation has been replaced. The liquid from the sample is squeezed well and transferred into a beaker. 400ml of water has been evaporated and dry the residue to constant mass at 100°c to 105°c.

3.4.4 Ether soluble substances

Test solution (5g) is extracted with ether for 4hour at a rate of at least 4 extractions per hour. Evaporate the ether extract and the residue was dried to constant mass at 100°c to 105°c.

3.5 OVERALL LIQUID TRANSPORT CHARACTERISTIC OF DEVELOPED SPUNLACE NONWOVEN

Liquid moisture management properties of nonwoven fabrics was determined by the method of AATCC (195) test method. This test method is based on water resistance, water repellency and water absorption characteristics of the fabric structure and the wicking characteristic of its fibers and yarn. This test method is focused on liquid moisture transport in flat state.

The samples were cut into 8×8 cm for five trails. The liquid moisture management properties of the samples were evaluated by placing a fabric specimen between two horizontal (upper and lower) electrical sensors each with seven concentric pins. A predetermined amount of test solution that aids the measurement of electrical conductivity changes are dropped onto the centre of the upward facing test specimen surface. The solution is free to move in three directions: radial spreading on the top surface, movement from the top surface to the bottom surface, and radial spreading on the bottom surface of the specimen. The electrical resistance

readings are used to calculate fabric liquid moisture content changes that quantify dynamic liquid moisture transport behaviours in multiple directions of the specimen.

Plate I

Moisture management tester

3.6 DEVELOPMENT OF NONWOVEN WOUND DRESSING PADS

The manufactured spunlace nonwoven was developed into six different wound dressing pad. Six different wound dressing pads have developed by the spunlace nonwoven and cotton wadding. The spunlace nonwoven is made of polyester, viscose and both in a different blend ratio. 260 – gram/meter^2 cotton wadding is used for the development of wound dressing pads. The cotton wadding cut into 10×10 cm. The spunlace nonwoven cut into 30×10 cm. then the cotton wadding is placed in-between the layers of spunlace nonwoven and sealed with ultrasonic sealing machine. The size of the wound dressing pad developed was 10×10 cm. After the completion of these procedure the gram/meter^2 of the total wound dressing pad was calculated. Details of developed Spunlace nonwoven wound dressing pad is given below in Table II

Plate II

Developed wound dressing pads

TABLE II

Details of Developed Wound Dressing Pads

WOUND DRESSING PADS	FIBERS USED	gram/meter^2
NWS 1	Polyester	550
NWS 2	Viscose	530
NWS 3	Viscose	560
NWS 4	Polyester, Viscose	560
NWS 5	Polyester, Viscose	600
NWS 6	Polyester, Viscose	560

3.7 PREPARATION OF WOUND EXUDATES

The exudates was prepared as a test solution for this study. The solution containing 142 mmol of sodium ions and 2.5 mmol of calcium ions has an ionic composition comparable to human wound exudate. It was prepared by dissolving 8.298g of sodium chloride and 0.368g of calcium chloride dihydrate in deionized water and made upto 1 litre in a volumetric flask. It should be warmed at (37 ± 1) ° c in oven for 30 min before the usage.

3.8 PHYSICAL TESTING OF DEVELOPED NONWOVEN DRESSING PAD

3.8.1 FREE SWELL ABSORPTIVE CAPACITY

3.8.1.1 Method I

Free swell absorptive capacity of primary wound dressing was determined by EN 13726-1 test methods. The test is intended to assess the performance of dressing, typically used on moderate to heavily exuding wounds, which will reach their maximum absorptive capacity within 30min, under the test conditions.

0.2g of sample was placed in petri dish. Exudate warmed at 37 ± 1° C was added corresponding to 40 times the mass of sample to the petri dish containing the sample and placed in oven for 30min at 37 ± 1 °C. Then the sample was hold for 30 sec to remove the excess exudate and weighed.

3.8.1.2 Method II

According to the standard WSP 240.3(10) it determines the free swell absorbency of a sample in a solution. The nonwoven bag with a dimension of 60 × 40 mm^2 to 60 × 85 mm^2 is prepared and the sides were sealed by allowing one side to drop the sample into the bag. 0.2g of the sample is made weight and placed into the nonwoven bag. The bag is submerged into exudate to be absorbed and allowed to soak for a period of 30min. then remove the sample from the fluid and hang it diagonally for 10minutes. So excess fluid would be removed and the bagis made weight. The absorbing capacity is calculated using the formula

$$X = \frac{\text{Final weight} - \text{initial weight} - \text{sample weight}}{\text{Sample weight}}$$

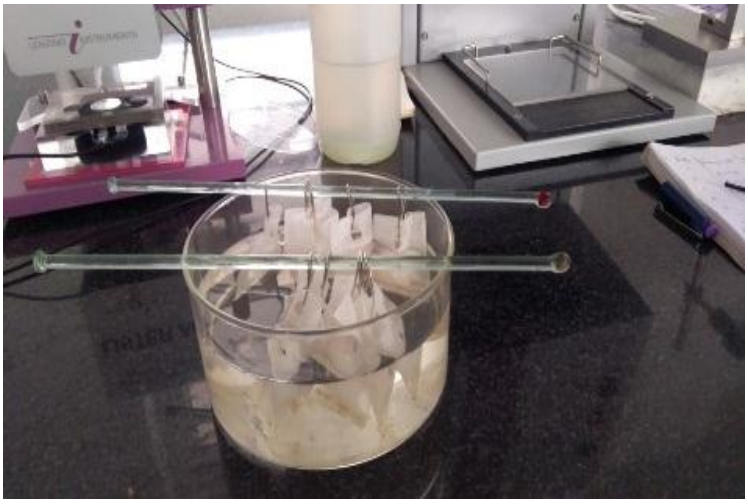

Plate III

Free swell absorbency test

3.8.2 STRIKE THROUGH TIME

It is the time taken for a volume of liquid to strike through the nonwoven sample. The exudate was taken in a burette and a known amount of exudate was discharged at a specified flow rate onto the wound dressing pad which is placed on reference absorbent pad. The time taken for the liquid to penetrate the nonwoven and reach the absorbent pad was determined using stopwatch. The time taken by the exudate to reach the absorbent pad was noted as a strike through time.

3.8.3 TIME OF ABSORBENCY

The exudate was taken in a burette and a specified amount of exudate (5ml) was discharged at a specified flow rate onto the wound dressing pad. The time taken for the complete absorption of the exudate was determined using stopwatch.

3.8.4 SURFACE DRYNESS

The surface dryness of the wound dressing pad was evaluated. The absorbent pad was weighed and recorded. The sample after strike through time was weighed. Absorbent pad was placed on the surface of the wound dressing pad and a force of 2kg was kept for 2min, then the

force is released and the absorbent pad is reweighed. Initial weight – final weight gives the surface dryness value.

3.8.5 Moisture Vapour Transmission Rate

Moisture vapor transmission rate **(**MVTR**)**, is a measure of the passage of moisture vapor through a substance. Moisture vapor transmission rate (MVTR) was determined according to the method of BS EN 13726 2. A test sample of 40 mm diameter was taken and fixed over a container of 35.7 mm inner diameter, containing 20 ml of exudate. The test sample container was weighed (W1) before the start of the test. Then the container is kept inside an incubator for 24 h (conditions maintained inside the incubator Temperature: (37 ± 1) ° c and RH 20%. After 24 h, the container was taken out and again weighed (W2).

MVTR is calculated based on the formula,

$X = (W_1 – W_2) \times 1000 \times 24/T$

Where,

X is MVTR (g/m^2/24 h)

W1 is the mass of the container, sample and liquid in grams

W2 is the mass of the container, sample and liquid in grams after the test duration

And T is the test period in h.

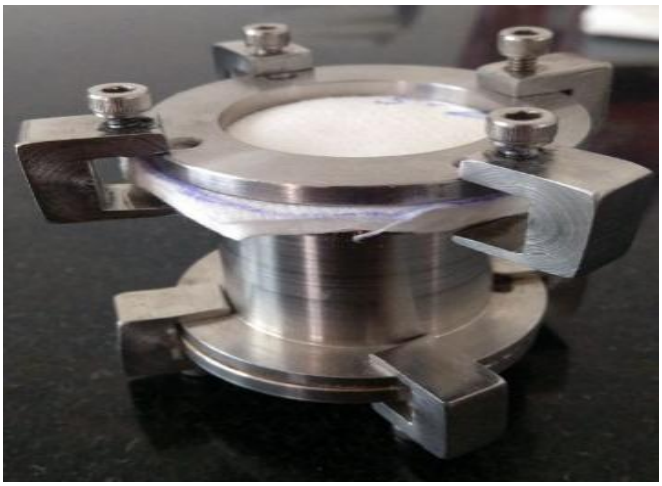

Plate IV

Paddington cup used for MVTR

4. RESULTS AND DISCUSSION

The results and discussion of the research work carried out on "effect of different types of spun lace nonwoven on wound pads exudates handling capacity characteristics" is presented under the following headings:

4.1 Moisture Management Test for Spunlace nonwoven

4.1.1 Top wetting time

4.1.2 Bottom wetting time

4.1.3 Top Absorption rate

4.1.4 Bottom Absorption rate

4.1.5 Top Max Wetted Radius

4.1.6 Bottom Max Wetted Radius

4.1. 7 Top Spreading speed

4.1.8 Bottom spreading speed

4.1.9 One Way Transport Capability

4.1.10 Overall moisture management capacity (OMMC)

4.2 Chemical Testing For Spunlace Nonwoven

4.2.1 acidity/alkalinity

4.2.2 Surface activity substances

4.2.3 Water soluble substances

4.2.4 Ether soluble substances

4.3 Physical Testing On Developed Wound Dressing Pad

4.3.1 Free Swell Absorbency

4.3.1.1 Method I

4.3.2.1 Method II

4.3.2 Strike through Time

4.3.3 Time of Absorbency

4.3.4 Surface Dryness

4.3.5 Moisture Vapour Transmission Rate

4.1 Moisture Management Test for Spunlace Nonwoven

4.1.1 Top wetting time

The top wetting time of developed nonwoven samples were determined and the results are presented in Table III and Fig 15.

Table III

Top Wetting time

Nonwoven Samples	Time (sec)
NWS 1	35.906
NWS 2	2.9952
NWS 3	**2.5272**
NWS 4	3.1828
NWS 5	26.7518
NWS 6	99.95

From Table III and Fig 15, it is clear that among six samples NWS-3 showed minimum top wetting time followed by sample NWS 2 and the sample NWS-6 gave lowest results. Decrease in top wetting time by sample NWS 3 may be due to its composition (100% viscose fiber). Maximum top wetting time in NWS 6 may be due to polyester which is hydrophobic in nature. There is no significant difference between NWS 2 and NWS 3 which may be due to similar fiber composition of 100 % viscose which differ in Gram/meter^2.

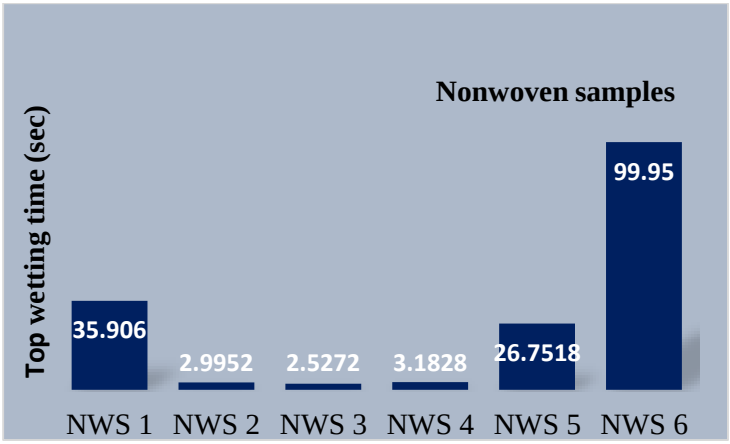

Figure 15
Top Wetting time

4.1.2 Bottom wetting time

The bottom wetting time of developed nonwoven samples were determined and the results are presented in Table IV and Fig 16

Table IV

Bottom wetting time

Nonwoven Samples	Time(sec)
NWS 1	74.769
NWS 2	2.5646
NWS 3	**2.5084**
NWS 4	3.0892
NWS 5	3.7816
NWS 6	5.5224

From Table IV and Fig 16, it is noted that among six samples NWS-3 which is composed of 100% viscose fiber showed minimum bottom wetting time when compared to other samples and the sample NWS-1 has recorded the maximum bottom wetting time. There is no significant difference between NWS 2 and NWS 3 which is 100 % viscose but differ in Gram/meter^2. Also there is no significant difference between NWS 4 and NWS 5 which is polyester and viscose blend with the blend ratio of 30:70 and 44:56 respectively.

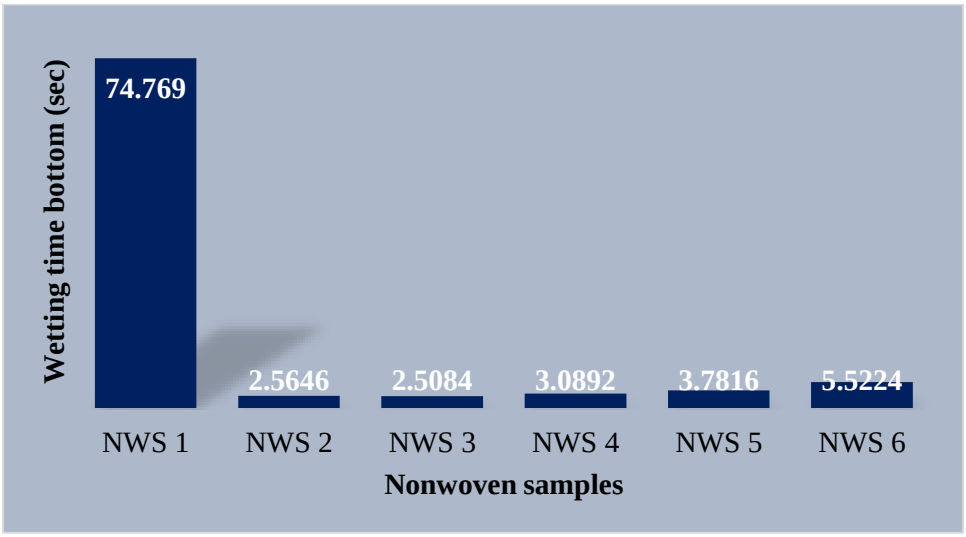

Figure 16
Bottom wetting time

4.1.3 Top Absorption rate

The top absorption rate of developed nonwoven samples were determined and the results are presented in Table V and Fig 17

Table V
Top Absorption rate

Nonwoven Sample	Top absorption rate (%/sec)
NWS 1	**140.6074**
NWS 2	33.1932
NWS 3	43.6847
NWS 4	35.3105
NWS 5	27.6281
NWS 6	27.4128

From Table V and Fig 17, it is clear that among six samples NWS-1 showed maximum top absorption rate when compared to other samples and the sample NWS-6 gave lowest results. NWS-1 which is composed of 100% polyester fiber has good wickability property and hence, gave maximum result than other samples, whereas NWS 6 which is composed of Polyester/viscose blend with a ratio of 35:65 gave lowest results. There is no significant difference between NWS 5 and NWS 6 which is polyester/viscose blend with a ratio of 44:56 and 35:65 respectively.

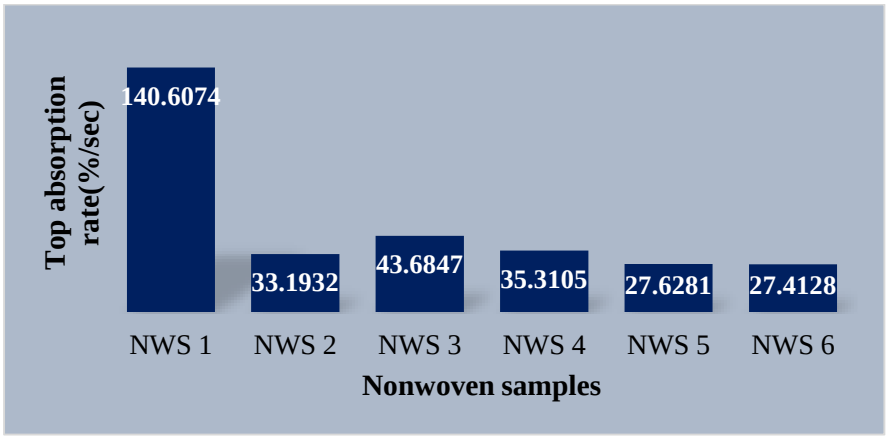

Figure 17
Top Absorption rate

4.1.4 Bottom Absorption rate

The bottom absorption rate of developed nonwoven samples were evaluated and the results are presented in Table VI and Fig 18

Table VI

Bottom Absorption rate

Nonwoven Sample	Bottom absorption rate (%/sec)
NWS 1	16.0221
NWS 2	47.9535
NWS 3	**54.894**
NWS 4	52.5265
NWS 5	48.8958
NWS 6	43.5841

From Table VI and Fig 18, it is clear that among six Samples NWS-3 showed higher bottom absorption rate than other samples, whereas the NWS-1 showed lowest results. It is noted that bottom absorption rate of NWS 1 is 3 times lesser than NWS 3. NWS 3 which is composed of 100% viscose fiber gave maximum bottom absorption rate, whereas 100% polyester NWS 1 gave minimum results.

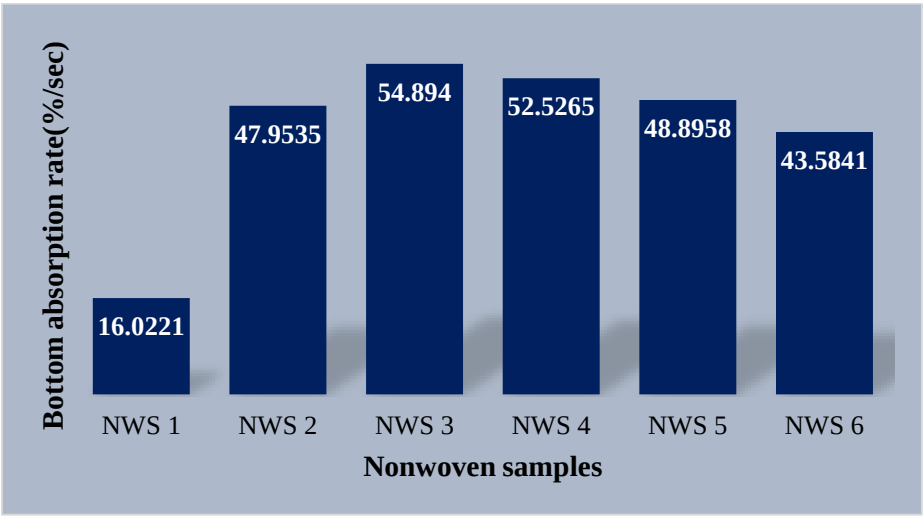

Figure 18
Bottom Absorption rate

4.1.5 Top Max Wetted Radius

The top max wetted radius of developed nonwoven samples were determined and the results are presented in Table VII and Fig 19

Table VII

Top Max Wetted Radius

Nonwoven Sample	Wetted radius (mm)
NWS 1	5
NWS 2	**26**
NWS 3	24
NWS 4	18
NWS 5	13
NWS 6	1

From Table VII and Fig 19, it is clear that among six samples the NWS-2 which is composed of 100% viscose showed maximum top max wetted radius whereas NWS-6 recorded the minimum top wetted radius. Maximum top wet radius in NWS 2 may be due to its fiber composition. There is no significant difference between NWS 2 and NWS 3 which is 100% viscose but differ in Gram/meter^2.

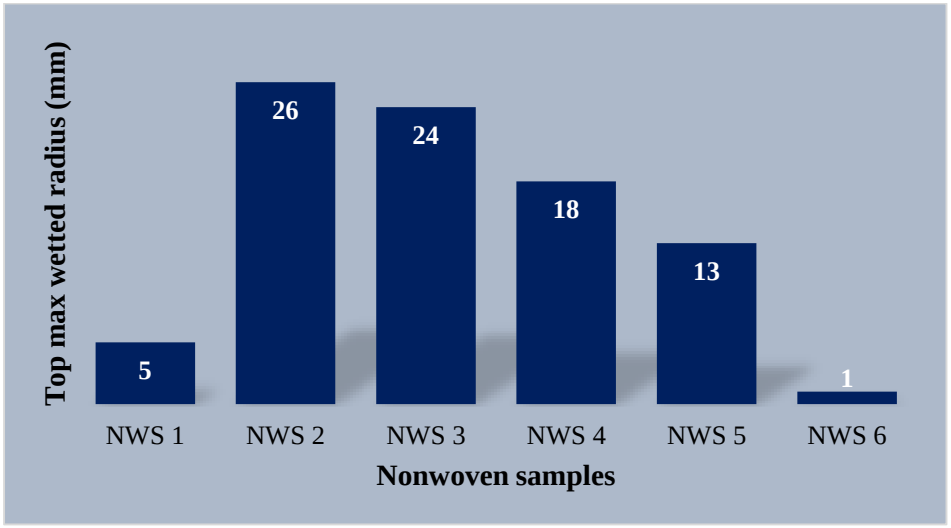

Figure 19

Top Max Wetted Radius

4.1.6 Bottom Max Wetted Radius

The bottom max wetted radius of developed nonwoven samples were determined and the results are presented in Table VIII and Fig 20

Table VIII
Bottom Max Wetted Radius

Nonwoven Sample	Wetted radius(mm)
NWS 1	4
NWS 2	**26**
NWS 3	25
NWS 4	19
NWS 5	14
NWS 6	5

From Table VIII and Fig 20, it is clear that among six Samples the NWS-2 which is composed of 100% viscose showed maximum Bottom max wetted radius whereas NWS-1 gave the minimum Bottom wetted radius. The NWS 2 gave maximum results due to their fiber composition. There is no significant difference between NWS 2 and NWS 3 which is 100% viscose but differ in Gram/meter^2.

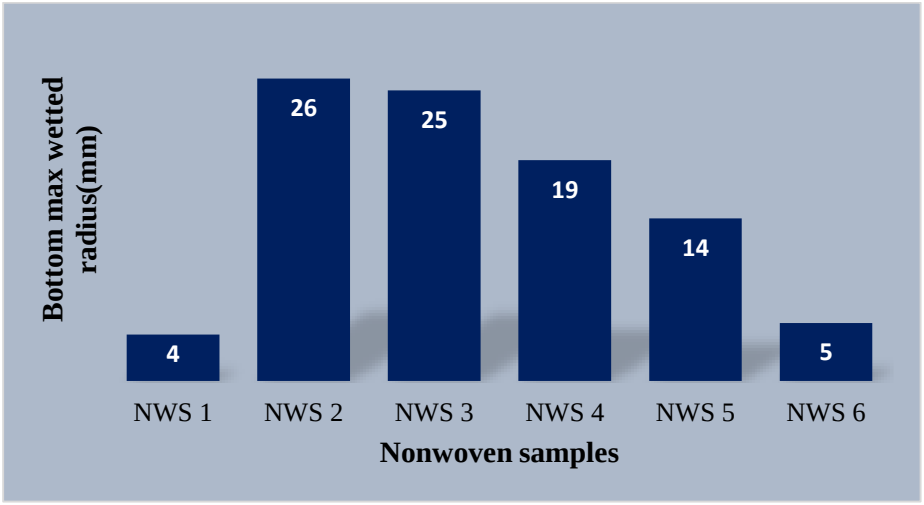

Figure 20
Bottom Max Wetted Radius

4.1.7 Top Spreading speed

The top spreading speed of developed nonwoven samples were determined and the results are presented in Table IX and Fig 21

Table IX

Top Spreading speed

Nonwoven Sample	Spreading speed(mm/sec)
NWS 1	0.2918
NWS 2	**6.2545**
NWS 3	5.6337
NWS 4	3.5957
NWS 5	2.5824
NWS 6	0.0502

Table IX and Fig 21 showed that NWS-2 has faster top spreading speed among the samples, whereas NWS-6 gave the lowest top spreading speed. NWS 2 recorded maximum spreading speed due to their fiber composition which is 100% viscose, whereas the NWS 6 has a fiber composition of Polyester /viscose with blend ratio of 35:65 showed the lowest spreading speed .

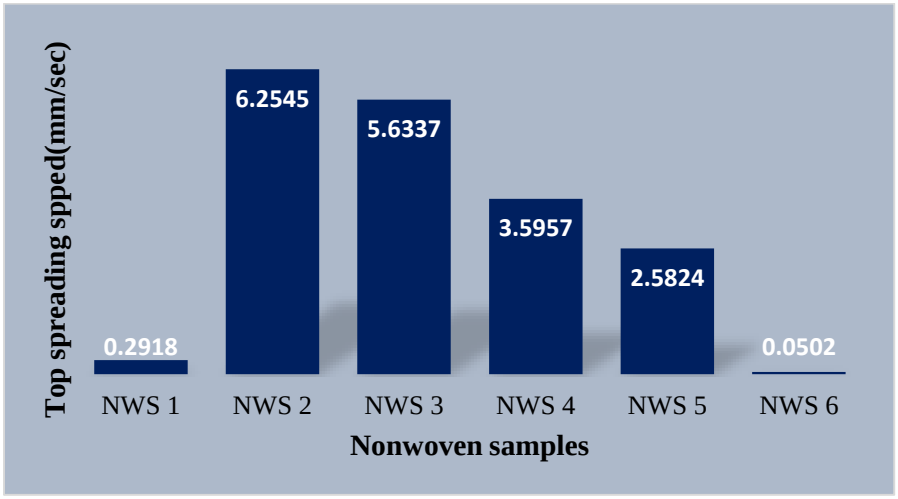

Figure 21
Top Spreading speed

4.1.8 Bottom spreading speed

The bottom spreading speed of developed nonwoven samples were determined and the results are presented in Table X and Fig 22

Table X

Bottom spreading speed

Nonwoven Sample	Spreading speed (mm/sec)
NWS 1	0.2296
NWS 2	**6.0144**
NWS 3	5.52
NWS 4	3.8903
NWS 5	2.7766
NWS 6	0.8784

From Table X and Fig 22, it is clear that among six Samples NWS-2 showed higher Bottom spreading speed when compared to other samples, while the NWS-1 gave lowest Bottom spreading speed. NWS 2 gave maximum bottom spreading speed due to their fiber composition of 100% viscose, while NWS 1 composed of 100% polyester gave lowest bottom spreading speed. There is no significant changes between NWS 2 and NWS 3 which is 100% viscose but differ in gram/meter$^{2.}$

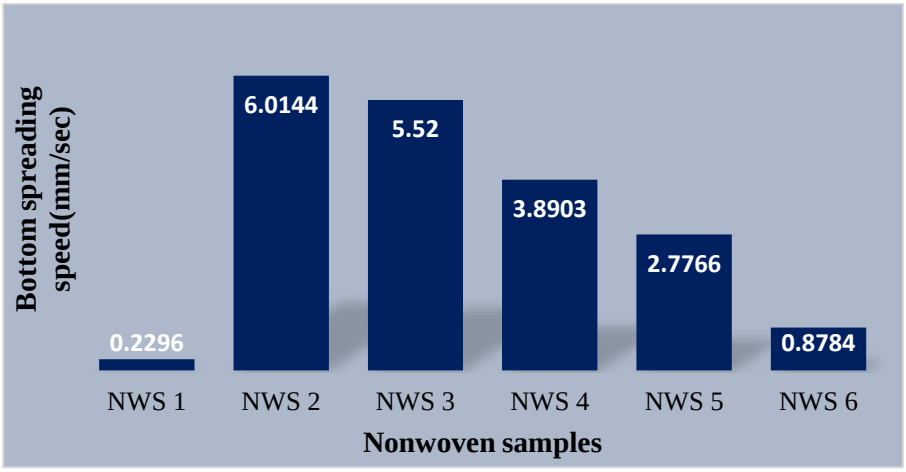

Figure 22
Bottom spreading speed

4.1.9 One way transport capability

The one way transport capability of developed nonwoven samples were determined and the results are presented in Table XI and Fig 23

Table XI
One way transport capability(R)

Nonwoven sample	One way transport capability (R)
NWS 1	-402.136
NWS 2	241.6946
NWS 3	183.5137
NWS 4	350.4763
NWS 5	275.0681
NWS 6	**708.6314**

From Table XI and Fig 23, it is noted that among six Samples NWS-6 showed maximum one way transport capability when compared to other samples, whereas NWS 1 gave minimum one way transport capability.

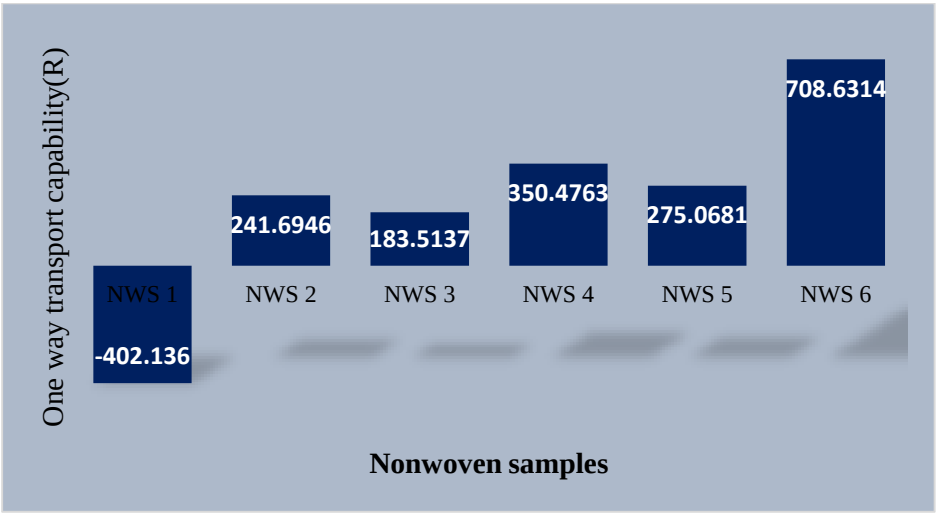

Figure 23
One way transport capability

4.1.9 Overall moisture management capacity (OMMC)

The overall moisture management capacity of developed nonwoven samples were determined and the results are presented in Table XII and Fig 24

Table XII
Overall moisture management capacity (OMMC)

Nonwoven Sample	OMMC
NWS 1	0.1261
NWS 2	0.6795
NWS 3	0.6342
NWS 4	**0.7842**
NWS 5	0.6218
NWS 6	0.5933

From Table XII and Fig 24, it is noted that among six samples NWS-4 showed maximum Overall moisture management capacity than other samples, while NWS-1 gave lowest overall moisture management capacity. From the finger print results the NWS 4 is declared as the moisture management fabric.

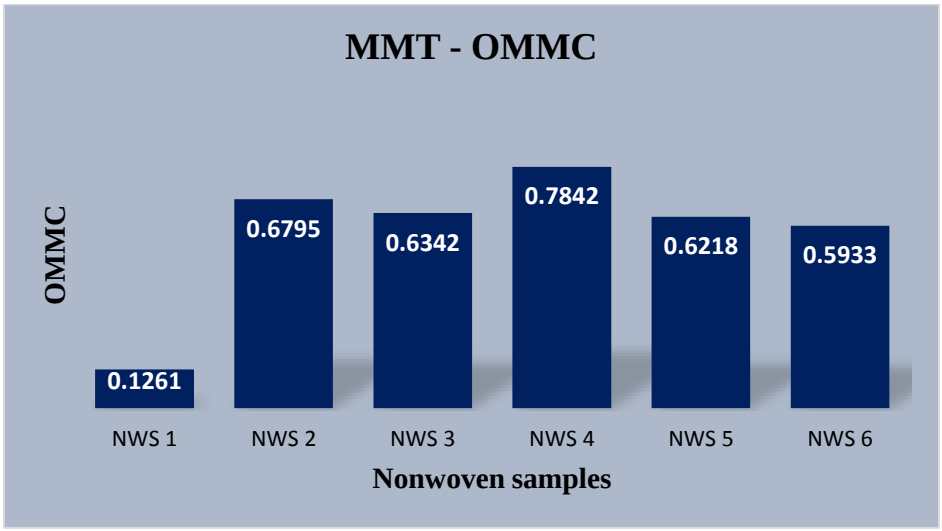

Figure 24
Overall moisture management capacity (OMMC)

4.2 Chemical Testing For Spunlace Nonwoven

4.2.1 Acidity/ Alkalinity

The presence of acidity/alkalinity is confirmed by the appearance of pink color in the solution. Absence of pink color in all the six samples indicate the absence of acidity/ alkalinity. Hence the selected samples could be utilized for preparing wound dressing pad.

4.2.2 Surface Activity Substances

The presence of surface activity substances where confirm when the foam appears after a vigorous shake and is noted in mm. The surface activity substances of developed nonwoven samples were determined and the results are presented in Table XIII

Table XIII

Surface Activity Substances

Nonwoven Sample	Surface activity substances
NWS 1	absent
NWS 2	absent
NWS 3	absent
NWS 4	8mm
NWS 5	7mm
NWS 6	3mm

From Table XI it is clear that sample 4 has high surface activity substances when compared to sample 5 and 6. It is also noted that surface activity substances was absent in NWS 1, NWS 2, and NWS 3. To conclude samples NWS 1, NWS 2 and NWS 3 are suitable for developing wound dressing pads as surface activity substances is absent.

4.2.3 Water Soluble Substances

The water soluble substances of developed nonwoven samples were determined and the results are presented in Table XIV and Fig 25

Table XIV

Water soluble substances

Nonwoven Sample	Water soluble substances (%)
NWS 1	0.10
NWS 2	0.12
NWS 3	0.23
NWS 4	0.11
NWS 5	0.22
NWS 6	0.27

The standard limit for the presence of water soluble substance should be less than 0.5% for the wound dressing pads. From Table XIV and Figure 25 it is noted that all six samples are within the limitation.

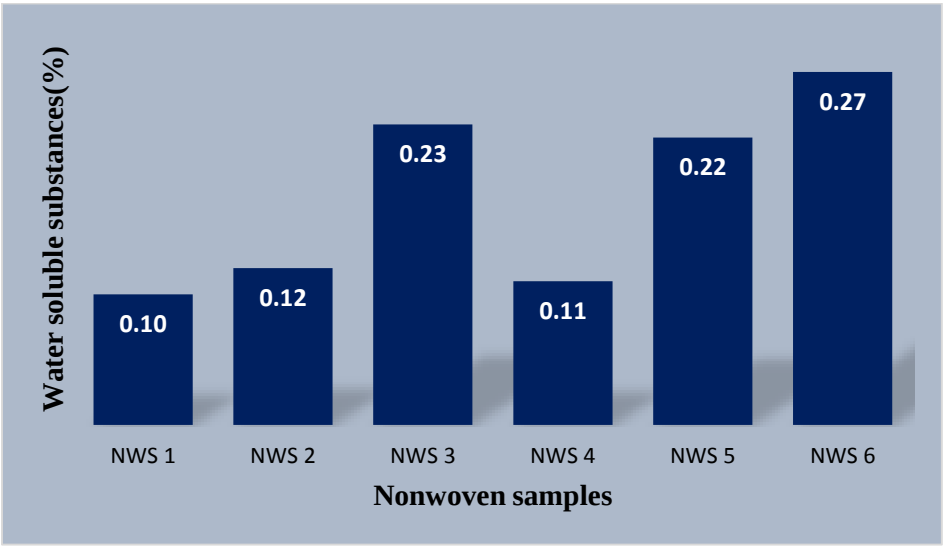

Figure 25

Water soluble substances

4.2.4 Ether Soluble Substances

The ether soluble substances of developed nonwoven samples were determined and the results are presented in Table XV and Fig 26

Table XV

Ether Soluble Substances

Nonwoven Sample	Ether soluble substances (%)
NWS 1	0.08
NWS 2	0.09
NWS 3	0.16
NWS 4	0.09
NWS 5	0.18
NWS 6	0.22

The standard limit for the presence of ether soluble substance should be less than 0.5% for the wound dressing pads. From Table XV and Figure 26 it is noted that all six samples are within the limitation.

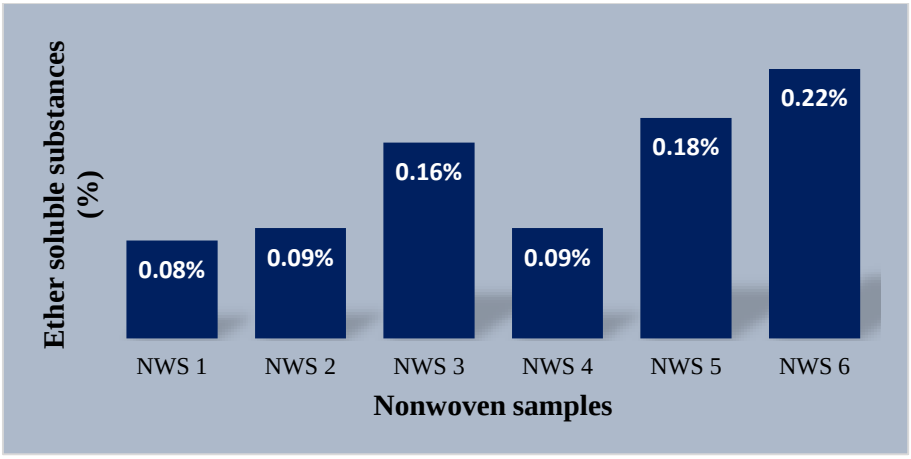

Figure 26
Ether Soluble Substances

4.3 Physical Testing On Developed Wound Dressing Pad

4.3.1Free Swell Absorbency

4.3.1.1 Method I

According to test method EN 13726 – 1 free swell absorbency of developed wound dressing pads were determined and the results are presented in Table XVI and Fig 27

Table XVI

Free Swell Absorbency (g/g)

Wound dressing pads	Mean	SD	F Value
NSW 1	14.5	0.36	0.9987
NSW 2	14.06	4.26	
NSW 3	14.57	0.46	
NSW 4	14.34	1.08	
NSW 5	14.88	0.63	
NSW 6	18.11	2.20	

From Table XVI and Fig 27, it is noted that among six Samples NSW-6 showed maximum free swell absorbency compared to other samples, while the NSW-2 gave lowest free swell absorbency.

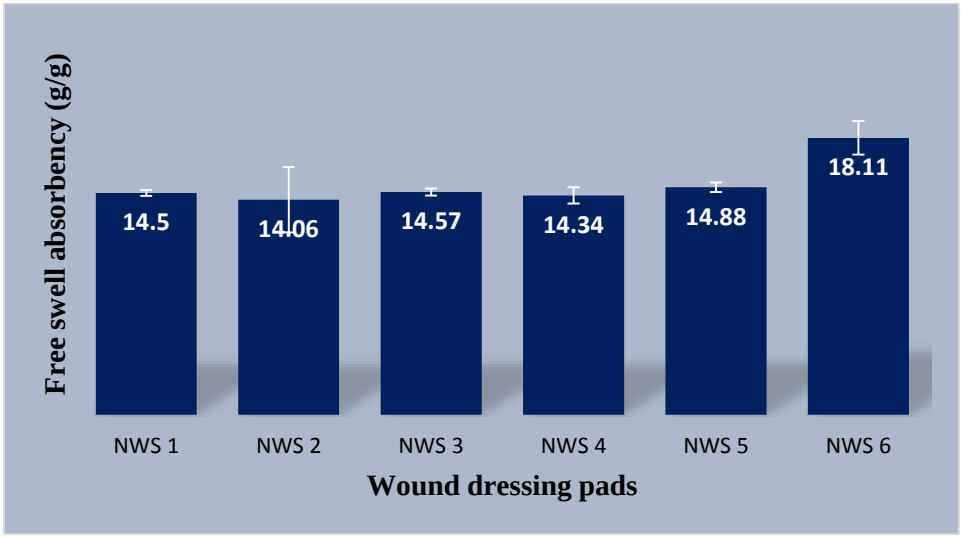

Figure 27

Free Swell Absorbency

4.3.1.2 Method II

According to test method WSP 240.3(10) free swell absorbency of developed wound dressing pads were determined and the results are presented in Table XVII and Fig 28

Table XVII

Free Swell Absorbency (g/g)

Wound dressing pads	Mean	SD	F Value
NSW 1	15.54	0.18	0.441
NSW 2	17.4	1.48	
NSW 3	16.3	1.94	
NSW 4	14.85	1.84	
NSW 5	14.9	0.87	
NSW 6	16.06	0.97	

From Table XVII and Fig 28, it is noted that among six samples NWS-2 showed maximum free swell absorbency, because of its fiber composition (100% viscose). The NWS 4 has Polyester/viscose blend with a ratio of 30:70 gave the minimum free swell absorbency.

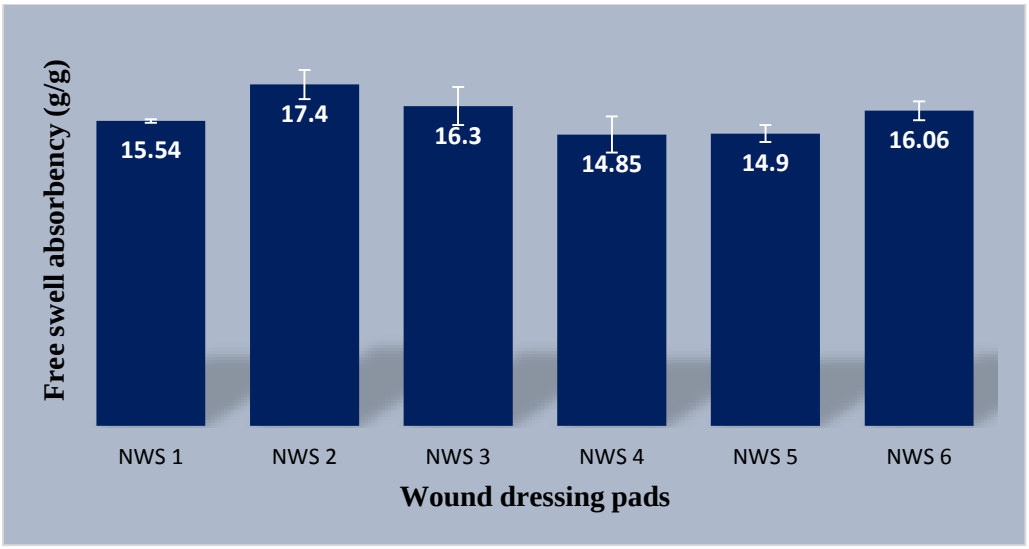

Figure 28

Free Swell Absorbency

4.3.2 Strike through time

The strike through time of developed wound dressing pads were determined and the results are presented in Table XVIII

Table XVIII

Strike Through time

Wound dressing pads	Strike Through	
	Time	ML
NSW 1	19.2 min	21
NSW 2	5.31 sec	21
NSW 3	18.15 sec	5.6
NSW 4	18.11 sec	6.6
NSW 5	11.91 sec	7.8
NSW 6	46.50 sec	17.2

From Table XVIII, it is clear that among the six samples NWS 1 and NWS 2 has absorbed large amount of exudates while NWS 3 absorb least amount of exudates. NWS 1 and NWS 2 have a same absorbent capacity but their strike through time varies because of the use of varied fibers. The NWS 1 is 100% polyester which takes time to penetrate the opposite side of the dressing, whereas NWS 2 is 100% viscose, so it penetrate faster to the opposite side but both have the capacity to hold same amount of exudates.

4.3.3 Time of Absorbency

The time of absorbency of developed wound dressing pads were determined and the results are presented in Table XIX and Fig 29

Table XIX

Time of Absorbency (sec)

Wound dressing pads	Mean	SD	F Value
NSW 1	1152	332.44	0.0161
NSW 2	6.26	0.55	
NSW 3	17.55	4.80	
NSW 4	17.66	4.11	
NSW 5	6.4	0.59	
NSW 6	32.46	19.01	

From Table XIX and Fig 29, it is noted that among six Samples NWS-2 showed minimum time of absorbency than other samples, while NWS-1 gave maximum time of absorbency. NWS 2 is composed of 100% viscose fiber which has a hydrophilic character that makes the time of absorbency at shorter duration.

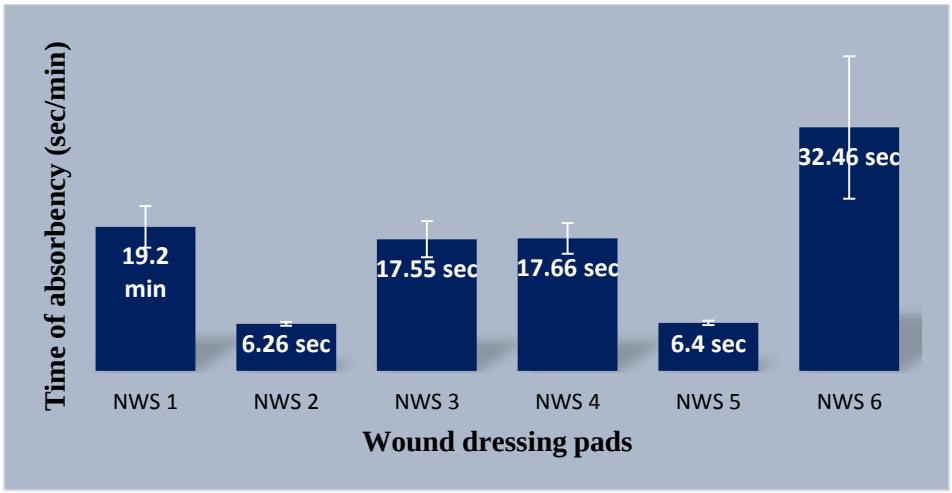

Figure 29

Time of Absorbency

4.3.4Surface Dryness

The surface dryness of developed wound dressing pads were determined and the results are presented in Table XX and Fig 30

Table XX
Surface Dryness (g)

Wound dressing pads	Mean	SD	F Value
NSW 1	8.285	0.99	0.0002
NSW 2	1.686	0.41	
NSW 3	2.435	1.06	
NSW 4	3.143	0.70	
NSW 5	4.468	0.86	
NSW 6	7.1936	1.30	

From Table XX and Fig 30, it is noted that among six Samples NWS-2 showed minimum surface dryness which is most applicable for wound dressing pad, whereas the NWS-1 gave maximum surface dryness. It is noted that surface dryness of NWS 2 is 5 times lower than NWS 1.

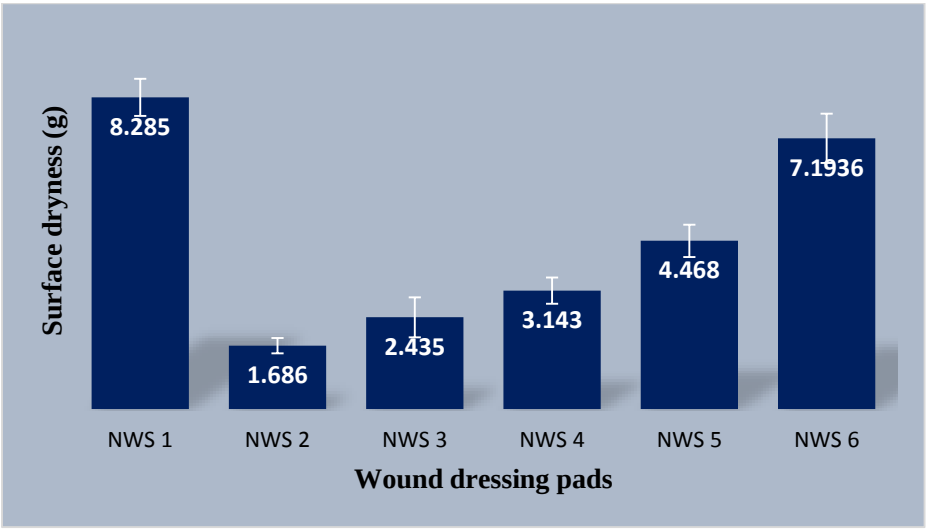

Figure 30
Surface Dryness

4.3.5 Moisture Vapour Transmission Rate

The moisture vapour transmission rate of developed wound dressing pads were determined and the results are presented in Table XXI and Fig 31

Table XXI

Moisture Vapour Transmission Rate ($g/m^2/24h$)

Wound dressing pads	Mean	SD	F Value
NSW 1	1402.86	128.46	0.0093
NSW 2	1523.97	42.82	
NSW 3	1564.34	71.36	
NSW 4	2046.34	153.54	
NSW 5	1770.71	70.87	
NSW 6	1921.05	212.62	

From Table XXI and Fig 31 it is noted that among six Samples NWS-4 showed higher Moisture vapour transmission rate when compared to other samples, whereas NWS-1 recorded minimum moisture vapour transmission rate.

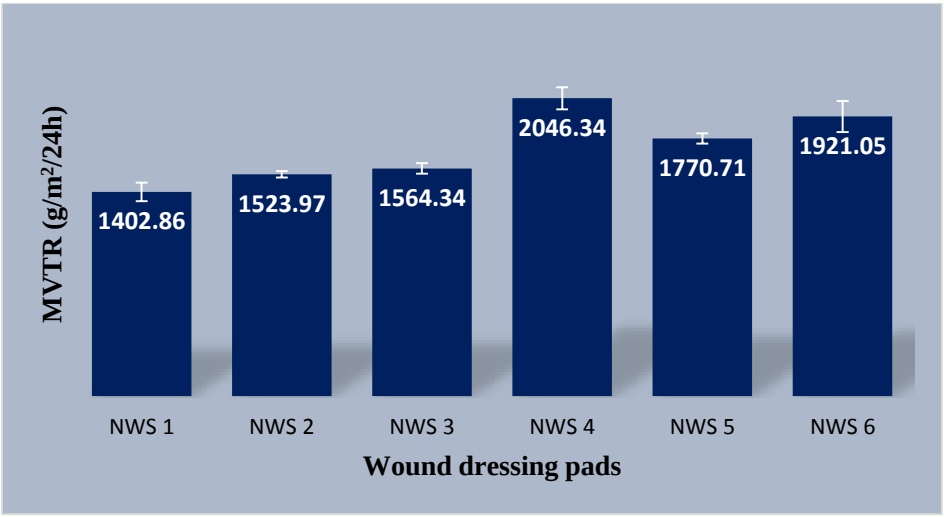

Figure 31
Moisture Vapour Transmission Rate

5. SUMMARY AND CONCLUSION

Wound management is one of the primary areas where critical attention is required. The wound management will be more effective by understanding or visualizing the changes in its amount, color, consistency and odour, which promotes the healing process, minimize maceration, discomfort and embarrassment for the patient. The exudate plays a major role in wound healing process by creating a moist environment and providing a sufficient nutrient. Exudate will be problematic to a patient when it is not managed well.

Successful wound management requires an approach to select the appropriate dressing with various properties. Dressing vary in the way they deal with exudate and with the fibers or particles of the dressing. Hence the development of an effective wound dressing material will be beneficial.

This research aims to explore the better wound management through examination of exudate handling capacity of different spun lace nonwoven fabrics and to compare the potential exudate handling of the wound dressing pad. Consequently, the present study **"Effect of different types of spun lace nonwoven on wound pads exudates handling capacity characteristics"** has been designed with the following objectives.

- To select raw material for the development of spunlace nonwoven with varied fiber composition
- To analyze the characteristics of developed spunlace nonwoven
- To develop nonwoven wound dressing pads
- To evaluate the characteristics of developed wound dressing pads

Experimental procedure

- The flexible quality of spun lace non-woven fabric like biodegradability, absorbency, air permeability, non -adherence to wound, sterilisation capability makes spun lace non-woven the suitable choice for developing wound dressing material.
- Hence spunlace nonwoven fabrics having varied fiber composition of polyester and viscose with varied gram/meter^2 (70 to100) were selected for fabricating the six different wound dressing pads.

- Liquid transport characteristics, acidity/alkalinity, surface activity substances, water soluble substances and ether soluble substances of the developed spunlace nonwoven samples were observed.
- Using cotton wadding and Spunlace nonwoven the wound dressing pad has been developed. The cotton wadding is cut into 10×10 cm. The spunlace nonwoven is cut into 30×10 cm. Then the cotton wadding is placed in-between the layers of spunlace nonwoven and sealed with ultrasonic sealing machine. The size of the wound dressing pad is 10×10 cm.
- The exudate has been prepared by dissolving 8.298g of sodium chloride and 0.368g of calcium chloride dihydrate in 1 litre deionized water, which is comparable to human wound exudate.
- Free swell absorbency, Strike through time, Time of absorbency, Surface dryness and Moisture vapour transmission rate were analyzed in developed Spunlace nonwoven wound dressing pads using exudates.
- Thus performance of both developed spunlace nonwoven and wound dressing pad was analyzed by determining the physical and chemical properties of the dressings.

Findings – on manufactured spunlace nonwoven

- Regarding top wetting time and bottom wetting time, sample NWS 3 was found to absorb the exudate in a short time duration which is most applicable for wound dressing pads.
- Sample NWS 1 showed maximum top absorption rate and NWS 3 has the maximum bottom absorption rate.
- For both top max wetted radius and bottom max wetted radius it is found that NWS 2 showed maximum wetted radius.
- Among the six different samples NWS 2 recorded maximum top spreading speed and bottom spreading speed.
- It is noted that one way transport capability was greater in the sample NWS 6.
- Sample NWS 4 showed maximum overall moisture management capacity value. This sample is considered as the moisture management fabric.
- Absence of acidity/alkalinity was found in all six samples.

- The surface activity substances was found to be absent in sample NWS 1, NWS 2 and NWS 3.
- The water soluble substances and ether soluble substances were found be within the limitation for the manufactured spunlace nonwoven.

Findings - On developed wound dressing pads

- NWS 6 wound dressing pad was found to show a well-mannered free swell absorbency when tested with EN 13726 -1 test method.
- NWS 2 wound dressing pad recorded a maximum free swell absorbency than other samples while tested with WSP -240.3(10).
- Up to the greater extend NWS 1 has hold higher amount of exudate and it took maximum time to penetrate the other side of the wound dressing pad.
- It is noted that the absorbency time is faster in NWS 2 when compared to other samples.
- The surface dryness results was found to be higher in NWS 2 when compared with other samples.
- With regard to the moisture vapour transmission rate NWS 4 showed maximum transmission rate of exudates.
- Among the wound dressing pads NWS 2 showed good top and bottom max wetted radius, time of absorbency, surface dryness and free swell absorbency.

Conclusion

Effective wound dressing pads have been developed with high potential. The present study proved that NWS 2 remains effective on exudate handling which is suitable for preparing wound dressing pads. It is proved that 100% viscose with 100 gram/meter^2 has assigned the good exudate handling capacity. The study has helped to enhance exudate handling properties of wound dressing pads with the suitable fiber on Spunlace nonwoven technique. Thus the results of this study has paved way for development of wound dressing pads for exudate handling which on commercialisation would be economical and effective.

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