JOURNAL of GREEN TECHNOLOGY and ENVIRONMENT

*Review Article*

# Current Potential Use of Antibacterial Textile Products in Medical Technical Textiles

**Naciye Sündüz Oğuz** *

Kastamonu University, Araç Rafet Vergili Vocational School, Department of Textile, Clothing, Shoes and Leather, 37150, Kastamonu/Türkiye
* Correspondence: noguz@kastamonu.edu.tr

**Abstract:** In recent years, medical technical textiles have gained great importance with increasing customer demands, technological developments and consumer awareness. People can be exposed to many microorganisms in daily life and these microorganisms can reproduce rapidly under the influence of appropriate temperature, humidity and nutrients. These microorganisms can cause infectious diseases and deaths. Bacteria formed on textile materials negatively affect human health, and cause loss of strength, bad odor and stain formation on textile surfaces. Nowadays, in order to prevent the harm given to the user and these negative situations occurring on the textile surface, the tendency towards antibacterial textile products, which are of great importance especially for the health sector, has increased. In this study, information is given about the importance of antibacterial textile products, which are of great importance for the health sector, their development and innovative approaches in this field.

**Keywords:** medical technical textiles; antibacterial textile products; medical applications

# Günümüzde Antibakteriyel Tekstil Ürünlerinin Tıbbi Teknik Tekstillerde Kullanım Potansiyeli

**Öz:** Son yıllarda artan müşteri talepleri, teknolojinin gelişmesi ve tüketicilerin bilinçlenmesi ile tıbbi teknik tekstiller büyük bir önem kazanmıştır. İnsanlar günlük hayatta pek çok mikroorganizmaya maruz kalabilmekte ve bu mikroorganizmalar uygun sıcaklık, nem ve besinin etkisi ile hızlı bir şekilde üreyebilmektedir. Bu mikroorganizmalar enfeksiyona dayalı hastalık oluşturabilmekte ve ölümlere sebep olabilmektedirler. Tekstil materyalleri üzerinde oluşan bakteriler insan sağlığını olumsuz etkilemekle birlikte, tekstil yüzeyinde mukavemet kaybı, kötü koku ve leke oluşumuna sebep olmaktadırlar. Günümüzde kullanıcıya verilen zararları ve tekstil yüzeyinde meydana gelen bu olumsuz durumları önlemek amacıyla bilhassa sağlık sektörü açısından büyük bir öneme sahip olan antibakteriyel tekstil ürünlerine yönelim artmıştır. Bu çalışmada sağlık sektörü açısından büyük bir öneme sahip olan antibakteriyel tekstil ürünlerinin önemi, gelişimi ve bu alanda yapılan yenilikçi yaklaşımlar konusunda bilgiler verilmiştir.

**Anahtar Kelimeler:** tıbbi teknik tekstil; antibakteriyel tekstil ürünleri; medikal uygulamalar

**Citation:** Oğuz, N. S. Current Potential Use of Antibacterial Textile Products in Medical Technical Textiles. Journal of GreenTech 2024, 2(2): 18-25. https://doi.org/10.5281/zenodo.14427385.

Received: 20.10.2024
Revised: 05.12.2024
Accepted: 13.12.2024
Published: 31.12.2024

## 1. Introduction

Textile products, which emerged with the need for human self-protection and covering, are used in many areas of daily life today for aesthetic purposes and due to their functional properties. From wet wipes to baby diapers, surgical sutures to tea bags, radiation protection products to flame retardant products, we use many textile materials in our daily lives and make our lives easier. Unlike traditional textile products, technical textiles have been developed for more specific purposes. This area is constantly growing and is used in many sectors such as fashion, agriculture, and health (Arslan & Arslan, 2024). Technical textiles are the fastest growing area of the textile sector, produced for their functional and performance properties rather than their decorative and aesthetic properties, and have a wide product range with the developments in technology. In recent years, studies in this field have gained great importance. Properties related to human health such as biodegradability, tissue compatibility, protection against microorganisms; mechanical properties such as reinforcement, elasticity, strength; protection against chemical, mechanical, radiation, thermal and electrical conditions; has changing properties such as waterproofing, filtration, conductivity, insulation, absorbency and drainage. Today, textile products are used in many areas such as medicine, protective clothing, sports equipment, transportation, industry, agriculture, construction, packaging and geotextiles with interdisciplinary studies outside of classical textile usage areas. Technical textiles include medical textiles used in hygienic and medical products; protective textiles that provide personal and property protection such as mechanical, chemical and radiation protection; agricultural textiles used in agriculture, horticulture, forestry and aquaculture; construction textiles used in buildings and construction; technical clothing used in clothing and shoes; vehicle textiles used in land, air, sea and railways; geotextiles used in environment, geology and construction fields; home textiles used in furniture, flooring and floor coverings; sports technical textiles used in sports and leisure activities; environmental textiles used for protection purposes; packtech technical textiles used in packaging are classified (Ekmen, 2005; Mecit et al., 2007; Karakan, 2009; Mecarcıöz et al., 2011).

Medical technical textiles are one of the most widely used technical textiles with the expansion of the field of medical applications. In this field, surgical gowns and covers, surgical sutures, medical masks, bandages, urine retention cloths, wet wipes, feminine hygiene products, waterproof bed covers, etc. are used, most of which are single-use products (Horrocks & Anand, 2002). Medical technical textiles are expected to have properties such as durability, flexibility and air permeability during examination and operational procedures (Akter et al., 2014). In addition, healthcare professionals use protective technical textile products for protection from radiation they are exposed to in the hospital environment.

## 2. Medical Textile Products

Biodegradation, staining and odor caused by bacteria settled in textile materials pose a threat to sterile environments (Akaydın and Kalkancı, 2014). Medical textile products are classified as single-use and multi-use. While single-use products such as surgical gowns are produced from nonwoven surfaces, multi-use products are produced from woven surfaces and undergo washing and sterilization processes (Pamuk and Öndoğan, 2008). In long-term operations, features such as air permeability and liquid repellency are of great importance in medical textile products. For this reason, medical textile products are very important in terms of the risk of bacterial exposure and comfort for patients and personnel (Üreyen et al., 2008). Medical textile products have the advantages of reducing infections, protecting personnel, being cost-effective, recommended by the World Health Organization (WHO), being comfortable, breathable, forming a barrier against blood and body fluids, suitable for sterilization, protecting against static electricity, flexible, soft and comfortable to use (Chınta & Veena, 2013).

A major change has been observed in medical textile products with the developments in science and the increase in social awareness. While previously only doctor's coats, cotton, gauze, and bandages were considered medical textile products, today textile-based implants are used in many different areas such as artificial tendons, artificial tissue, and biodegradable suture materials.

**Table 1.** Classification of Medical Textiles (Akter et al., 2014).

| Fiber Type | Fabric Structure | Application Area |
|---|---|---|
| Cotton, viscose, lyocell, alginate, chitosan, silk | Nonwoven surface | Absorbent pad |
| Cotton, viscose, lyocell | Woven, knitted, nonwoven surface | Wound contact layer |
| Cotton, viscose, lyocell polyamide, plastic films | Woven, nonwoven surface | Base material |
| Elastomeric, Cotton, viscose, lyocell | Woven, knitted, nonwoven | Simple non-elastic and elastic bandages |
| Elastomeric, Cotton, viscose, lyocell | Woven, knitted, nonwoven | Highly reinforced bandages |
| Elastomeric, Cotton, viscose, lyocell, polyester | Woven, knitted | Compression bandages |
| Cotton, viscose, plastic films, polyurethane, polyester, glass | Woven, nonwoven surface | Orthopedic bandages |
| Polypropylene | Woven, knitted, nonwoven surface | Band-aid |
| Cotton, viscose, lyocell, alginate, chitosan | Woven, knitted, nonwoven surface | Band-aid, gauze |
| Cotton, viscose, cellulosic (pulp, polylactic, polyglycolide) | Nonwoven surface | Medical materials in the form of wadding or interlining |
| Carbon | Spunlaid, nonwoven | Artificial vein or organ |
| Kolajen, poliglikolid, polilaktik, polyester, poliamid, polipropilen | Braided, mono-filament | Biodegradable sutures |
| Polyethylene, polyester, collagen, silk | Braided, mono-filament | Non-biodegradable sutures |
| Polyamide | Woven, braided | Artificial tendon |
| Polyamide, Polyester, carbon, collagen, low density polyethylene | Braided | Artificial cartilage and artificial ligaments |
| Chitin, polymethylmethacrylate | Nonwoven surface | Artificial skin |
| Silicon, collagen, polyacetyl | Nonwoven surface | Contact lens and artificial cornea |
| Polyethylene | Nonwoven surface | Artificial joint and bone |

When Table 1 is examined, it is seen that cotton fiber is primarily preferred in bandages and dressings, and nonwoven surface is the most frequently used. It is seen that spunlaid, carbon fiber and nonwoven surface are used in the production of artificial veins and artificial organs (Akter et al., 2014).

Medical textile products are defined by categorizing them as follows.

***Implantable Products***: These are materials that have the ability to degrade inside the body and can be placed inside the body by assuming the role of auxiliary function in organ transplants. Examples include surgical sutures (biodegradable or non-biodegradable), cardiovascular implants (vascular grafts, heart valves), orthopedic implants (artificial joints, bones), soft tissue implants (tendons, ligaments, cartilage, muscle, skin, contact lenses, artificial cornea) (Adanur, 2017; Emek, 2005; Akter et al., 2014).

***Non-implantable Products***: These are products used outside the body. Examples include wound dressings, gauze, tampons and bandages (Adanur, 2017; Akter et al., 2014).

Extracorporeal Products: These are artificial organs that have functional properties and are used to purify blood and perform the functions of internal organs in operations. Examples include artificial kidneys, artificial livers and mechanical lungs (Adanur, 2017; Akter et al., 2014; Horrocks & Anands, 2003).

***Care and Hygiene Products***: These are medical clothing and equipment used in medical practices to ensure the health and safety of healthcare personnel. Examples include surgical gowns, masks, gloves, bed sheets, urine retention pads and sanitary pads (Adanur, 2017; Emek, 2005; Akter et al., 2014).

Biocompatible polymers are especially preferred in medical textile products that come into contact with the skin and internal organs. Antibacterial, water-repellent and breathable products are preferred in products such as personnel clothing, surgical gowns, hospital linens (Zhumagaziyeva, 2021).

Textile products used in the medical field are used in internal applications such as drug delivery systems, soft tissue implants, cardiovascular implants and external applications such as wound and burn dressings, hygiene products. Some of the textile products used in the medical field are shown in Figure 1. (Zhumagaziyeva, 2021). Wound dressings help the wound heal quickly and hygienically. Artificial textile vessels used for arterial and venous autografts can replace problematic blood vessels and are expected to have natural vascular properties. Antibacterial silver ion masks are important to protect the user from bacteria. In order to ensure that the patient continues his normal life, an artificial kidney that performs the same function is used instead of a kidney that cannot be used or is working problematically. Surgical sutures; are sterile, synthetic or natural materials used to combine body tissues, fix prostheses, stop bleeding and connect the ends of tubular structures. Incision film is a transparent, air-permeable and hypoallergenic barrier product that prevents bacterial transfer by covering the surgical site (Zhumagaziyeva, 2021; Gemci & Ulcay, 2004; Eren & Ulcay, 2010; Gül, 2007; Demirağ et al., 2007; Felix Nonwovens, Films and Laminates, 2024).

**Figure 1.** **(a)** Hydrocolloid dressing; **(b)** Artificial vein ; **(c)** Silver ion mask **d)** Artificial kidneys; **e)** Monofilament surgical thread ; **f)** Incision film Zhumagaziyeva, 2021; İnan & Şeker, 2021, Salani et al., 2018; Chellamani et al.,. 2013; Felix Nonwovens, Films and Laminates, 2024).

### 2.1. Healing of Damaged Tissues and Organs Using Textile Products

With their biomimetic properties and cell regeneration-promoting structures, the use of nanofibers in wound dressings, stopping bleeding, preventing infection and tissue scaffolds contributes to tissue healing (Rošic et al., 2013). For this purpose, artificial kidney, artificial liver, artificial heart and artificial textile vein are used (Ersoy et al., 2015).

### 2.2. Wound and Burn Dressings

Traditional wound dressings consist of gauze, bandages and plasters. They require regular changes and are limited in the wound healing process. Modern wound dressings include varieties such as hydrocolloid, hydrogel and foam. They accelerate healing by providing a moist environment on the wound surface. Their most important features are that they are biocompatible and biodegradable, microbial control and infection prevention, easy to use and economical (Souto et al., 2020, Zhumagaziyeva, 2021). In medical textiles, film dressings, hydrocolloids, alginates, hydrofiber dressings, foam dressings, hydrogels, collagens and antimicrobial dressings are used as wound and burn dressings (Mirasoğlu, 2024).

Medical textiles are widely used for surgical and hygienic purposes. However, the increasing demand for disposable products increases waste generation. The environmental impacts of these wastes can be reduced with recycling and reuse strategies. For sustainability, the circular economy model should be adopted, products should be produced from biodegradable materials and recycling processes should be improved (Öncü & Kaygusuz, 2023).

### 2.3. Nonwoven Medical Textiles

The medical textile market is based on nonwoven products with their high performance and easy-to-change features. They are used in a wide range of areas such as diapers, dressings, gauze, surgical drapes and garments, hospital gowns (Zhumagaziyeva, 2021).

## 3. Antibacterial Textiles

People are in constant contact with bacteria that can multiply rapidly under suitable conditions in their daily lives. These microorganisms can cause bad odors, infections and product spoilage. The substances used in antibacterial textiles should be non-toxic, prevent bad odors and should not harm human health. Features such as flexibility, comfort, strength and breathability should be preserved. Many bacteria develop at 30-37°C, and food sources such as skin residues cause microorganisms to multiply rapidly on textile surfaces. Antibacterial tests are applied to detect the decrease in the number of microorganisms. Agar-based inhibition zone tests are applied qualitatively and bacterial count tests are applied quantitatively. AATCC 147 is widely used in the qualitative test method, and AATCC 100 and SNV 195- 920 and 921 in the quantitative test method. AATCC 147 and AATCC 174 test methods are especially suitable for hydrophilic textile materials and antimicrobial chemicals released from the surface. In quantitative methods, the amount of live microorganisms is measured after the appropriate contact time. Shake Flask method uses more microorganism cultures, while AATCC 100 method uses less microorganism cultures. The Japanese JIS L1902 standard has been developed and applied as the Hohenstein test method. The AATCC 100 method is a reliable method to numerically evaluate antibacterial activity, but it is technically demanding and time consuming (Service, 1998; Lindemann, 2000; Thiry, 2001; Mucha et al., 2002). Almost all antibacterial textile products have antibacterial properties against gram-positive *S. aureus* bacteria. *Staphylococcus aureus, Streptococcus pneumoniae, Mycobacterium tuberculosis, Escherichia coli, Klebsiella pneumoniae, Pseudomonas aeruginosa, Proteus mirabilis, Salmonella typhosa* and *Shigella dysenteriae* bacteria are microorganisms used in the medical field to determine antimicrobial activity. Gram-positive and gram-negative bacteria are used in antibacterial tests. Gram-positive *S. aureus* bacteria are the main cause of cross-infection in hospitals. Gram-negative *E. coli* and *P. aeruginosa* bacteria are the most troublesome bacteria in burn wounds. *S. aureus* bacteria cause 19% and *E. coli* bacteria cause 11% of surgical infections (Rowell, 2012). In order to prevent unwanted situations caused by microorganisms, it is desired for medical technical textile products to have antibacterial properties. While substances such as silver, zinc, mercury, tin, titanium and lead have the ability to kill microorganisms, they can have toxic effects on humans and the environment during application. Therefore, attention should be paid to the usage rate. Antibacterial textile products should not harm humans and the environment and should not adversely affect the properties of the textile product. Alginate, soy and chitosan are naturally antibacterial fibers. Natural fibers such as cotton, linen and wool are more sensitive to bacteria than synthetic fibers due to their porous hydrophilic structure. Antibacterial fabric finishing is done with chemical finishing agents. The antibacterial properties on textile surfaces can decrease with the washing process. Antibacterial activity is maintained by applying high concentration finishing agents (Sarı, 2020).

Antibacterial properties are imparted to fibers through surface applications, placement of chemical substances into the fiber structure and chemical combination (Altınok, 2008). In antibacterial finishing processes, one of the following methods is used: impregnation, shrinkage, coating transfer, vacuum application, maximum liquor application, spraying, foam application. Coating, impregnation and spraying methods are the most commonly used methods (Seventekin et al., 2001). The most important antibacterial substances are metals, halogens, phenol and its derivatives, alcohols, zeolites, oxidizing agents, chitin, chitosan biquanidines, isothiazolones, ammonium compounds and organotin compounds. (Devrent and Yılmaz, 2004, Seong et al., 1999).

## 4. Development of Antibacterial Medical Technical Textile Products

Antibacterial medical technical textile products increase the quality of healthcare services, diversify biomedical applications and general living standards with innovations in this field.

Anita et al. (2011), applied copper oxide nanoparticles to cotton fabric by microencapsulating them. It was observed that the fabric coated with encapsulated copper oxide has antibacterial properties and can be used in the production of medical clothing.

Dizaj et al. (2014), used metal and metal oxide nanoparticles and found that particle size is the main parameter determining antimicrobial efficiency. It was observed that the toxicity of metal and metal oxide nanoparticles can be used as an alternative to antibiotics and disinfectants in medical applications by minimizing them.

Combria et al. (2019), investigated the antibacterial properties and drug release behaviors of gentamicin sulfate (GS) loaded nanofibers using polylactic acid (PLA), polycaprolactone (PCL) and polylacticcoglycolic acid (PLGA). It was observed that the nanosurfaces were released immediately and had antibacterial properties against *S. aureus* bacteria.

Ferreira et al. (2019), applied polydimethylsiloxane (PDMS) and silver nanoparticle based antimicrobial coating studies using the solution blowing spray method. It was observed that the surfaces had antibacterial properties against *E. coli* and *S. aureus* bacteria.

Orhan et al. (2019), investigated the antibacterial properties of silver-containing cotton and cotton/polyester blend surfaces after 7 days of use by doctors and patients. It was found that antibacterial-treated doctor's gowns and sheets used for patients had high antibacterial properties against *S. aureus* and *E. coli* bacteria; It is seen that its use in crowded places such as hospitals and hotels will provide advantages.

Xia et al. (2019), aimed to produce an antibacterial wound dressing loaded with ciprofloxacin (CPF) drug using polylactic acid/gelatin (PLA/GE) nanofibers. Centrifugal spinning method was used in the study. It was seen that drug-loaded PLA/GE nanofibers can be used as an antibacterial wound dressing.

Abdoli et al. (2020), aimed to produce electroextruded nanofibrous tissue scaffolds for a transdermal drug delivery system using tetracycline active ingredient containing graphene oxide and polyvinyl alcohol and gum tragacanth polymer mixture. It was seen that the nanofibrous composite structure has antibacterial properties and can be used in other biomedical fields with controlled drug release.

Nematpour et al. (2020), produced nanofibrous medical textile surfaces containing tetracycline loaded dextran, PCL and graphene oxide for transdermal drug delivery and wound dressing by electroextrusion method. It was observed that the composite material has a strong antibacterial property against *E.coli* and *S.aureus* and can be used as a dermal wound dressing.

Güngör et al. (2021), aimed to use cross-linked gelatin nanofibers as a wound dressing using the centrifugal spinning method. Silver nitrate ($AgNO_3$) was used to give the surface antibacterial properties. It was observed that the obtained surfaces were wound dressings with antibacterial properties against *S.aureus* and *E.coli* bacteria.

Snari et al. (2022), obtained surfaces consisting of a sodium polylactate/polyvinyl alcohol/ZnO mixture with the solution blowing technique in order to obtain wound dressings containing biocompatible nanofibers with antibacterial activity. It was observed that the surface gained antibacterial properties, but ZnO reduced cell viability.

Kale and Altun (2022), wanted to create an environmentally friendly alternative to medical masks due to the fact that disposable masks, which are one of the most used products, are not biodegradable and cause increasing damage to the environment with the "Covid-19" pandemic. An environmentally friendly alternative to conventional methods was offered for medical masks by designing a mask with origami folding using kombucha tea as a cellulose source.

Kertmen et al. (2022), examined the antibacterial properties of fabrics produced using different knitted and woven surfaces, different yarn counts and different spinning methods. It was found that knitted fabrics with antibacterial finish and knitted fabric samples containing silver fiber with antibacterial properties were the most suitable fabrics according to performance tests.

Pektaş (2024), used polyvinyl alcohol, polyamide 6, polyamide 6.6, polyacrylonitrile, polylactic acid, polymethyl methacrylate, polyvinyl pyrrolidone, polycaprolactan, cellulose acetate and collagen polymers, vegetable and animal oils, ozonated forms of these oils and immortelle essential oil in order to produce a medical textile surface containing nanofibers with antibacterial and antifungal properties. It was observed that the obtained surfaces could be used as wound healing medical textile surfaces.

When the studies are examined, it is seen that antibacterial medical technical textile products are open to development and promising medical textile products

## 5. Conclusions

Technical textiles, as a rapidly developing field, aim to meet the needs of humanity and improve living standards with an interdisciplinary approach. Antibacterial textile products, as one of the most important innovative elements of medical technical textiles, play a critical role in the healthcare sector in terms of improving the quality of life of patients and reducing infection risks. These products provide an effective solution in preventing infectious diseases caused by microorganisms, especially in hospital environments, while also providing great convenience in home care, elderly and bedridden patient groups.

In the development of textile products with antibacterial properties; the use of biological and chemical agents such as silver ions, zinc oxide nanoparticles, and plant extracts increases the effectiveness of the products and offers more sustainable solutions. However, the compatibility of these products with human health, their effects on the environment and cost-effectiveness are of critical importance for future research. It is important for antibacterial textile products to maintain their antibacterial effectiveness for a long time, to prioritize the use of natural and biodegradable materials, and to design products that are accessible to the masses at low cost.

Antibacterial textile products offer innovative approaches in the field of medical technical textiles, providing an effective solution in infection control and a valuable contribution to the health sector. The development and widespread use of these products will play a critical role not only in terms of individual health, but also in protecting public health and ensuring a sustainable and quality life.

**Funding:** This research received no external funding.

## References

Abdoli, M., Sadrjavadi, K., Arkan, E., Zangeneh, M.M., Moradi, S., Zangeneh, A., Khaledian, S., (2020). Polyvinyl Alcohol/Gum Tragacanth/Graphene Oxide Composite Nanofiber for Antibiotic Delivery. Journal of Drug Delivery Science and Technology, 60, 102044.
Adanur, S. (2017). Wellington Sears handbook of industrial textiles. Routledge.
Akaydın, M., & Kalkancı, M. (2014). Hastane giysisi olarak kullanılan kumaşların antibakteriyel özellikleri üzerine bir araştırma. Süleyman Demirel University Faculty of Arts and Science Journal of Science, 9(1), 20-34.
Akter, S., Azim, A. Y. M. A., & Al Faruque, M. A. (2014). Medical textiles: significance and future prospect in Bangladesh. European Scientific Journal, 10(12):488-502.
Altınok, U.B. (2008). Tekstil Yüzeylerinin Antibakteriyel Özelliklerinin Araştırılması. Süleyman Demirel Üniversitesi, Fen Bilimleri Enstitüsü, Tekstil Mühendisliği Ana Bilim Dalı, Yüksek Lisans Tezi, 97 s, Isparta.
Anita S., Ramachandran T., Rajendran R., Koushik C. V., Mahalakshmi M. (2011). A study of the antimicrobial property of encapsulated copper oxide nanoparticles on cotton fabric, Textile Research Journal, 81(10) syf. 1081–1088.
Arslan, İ. K., & Arslan, M. B. (2024). Cumhuriyetimizin Yüzüncü Yılında Türk Tekstil Sektöründeki Gelecek Arayışları Bağlamında Stratejik Bir Değişim Dönüşüm Unsuru Olarak Teknik Tekstiller. Avrasya Dosyası, 14(2), 117-137.
Chınta, S.K., Veena, K.V. (2013). International Journal of Latest Trend in Engineering and Technology (IJLTET) 2(1) 142-145.
Coimbra, P., Freitas, J.P., Gonçalves, T., Gil, M.H., Figueiredo, M., (2019). Preparation of Gentamicin Sulfate Eluting Fiber Mats by Emulsion and by Suspension Electrospinning. Materials Science and Engineering: C, 94, 86-93.
Demirağ A, Ercan S, Küçükaksu S, Özmen M. (2007). Yapay organlar. TÜBİTAK Bilim Teknik Dergisi.; 9:4-15
Devrent, N., Yılmaz, N.D. (2004). Tekstil Endüstrisinde Kullanılan Antimikrobiyal Lifler. Nonwoven Technical Textiles Technology Dergisi, 4: 48-55.
Dizaj S. M., Lotfipour F., Barzegar-Jalali M., Zarrintan H., Adibkia K., (2014). Antimicrobial activity of the metals and metal oxide nanoparticles, Materials Science and Engineering C, 44, 278–284.
Ekmen, Ö., (2005). Hortumlarda Kullanılan Teknik Tekstil Yapıları Hakkında Bazı Çalışmalar. Dokuz Eylül Üniversitesi, Fen Bilimleri Enstitüsü, Tekstil Mühendisliği Anabilim Dalı, Yüksek Lisans Tezi, 132 s, İzmir.
Emek, A. (2005). Teknik tekstiller dünya pazarı, Türkiye'nin üretim ve ihraç imkanları. İGEME.
Eren, S., & Ulcay, Y. (2010). Yapay Tekstil Damarları. Tekstil Teknolojileri Elektronik Dergisi, 4(1), 35-47.
Ersoy, Y., Duran, M., & Tayyar, A. (2015). Tıbbi tekstiller ve yara örtüsü. Düzce Üniversitesi Bilim ve Teknoloji Dergisi, 3(2), 451-458.
Felix Nonwovens, Films and Laminates, (2024, Deceember 12). https://www.felixnonwovens.com/urunler/cerrahi-insizyon-drep-insizyon-filmi-54.
Ferreira, T. P. M., Nepomuceno, N. C., Medeiros, E. L. G., Medeiros, E. S., Sampaio, F. C., Oliveira, J. E., Oliveira, M. P., Galvão, L. S., Bulhões, E. O., & Santos, A. S. F. (2019). Antimicrobial coatings based on poly(dimethyl siloxane) and silver nanoparticles by solution blow spraying. Progress in Organic Coatings, 133(February), 19–26.
Gemci, R., Ulcay, Y. (2004). Ameliyat İplikleri Tipleri Özellikleri ve Krome Katgüt İle Normal Katgüt Arasındaki Mukavemet Farkları. Uludağ Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi 9(2), 95-105.
Güngör, M., Sağırlı, M. N., Çalışır, M. D., Selçuk, Ş., & Kılıç, A. (2021). Developing centrifugal spun thermally cross-linked gelatinbased fibrous biomats for antibacterial wound dressing applications. Polymer Engineering and Science, 61, 2311–2322.
Gül, Ü. (2007). Yara Örtüleri. Türkiye Klinikleri Dahili Tıp Bilimleri Dergisi 3(48), 18-23.
Horrocks, A. R., & Anand, S. (2002). Teknik tekstiller el kitabı. Türk Tekstil Vakfı.
İnan, A. T., & Şeker, M. M. (2021). Elektrospinning yöntemiyle üretilmiş farklı çaplardaki yapay damarların mekanik özelliklerinin incelenmesi. International Journal of Advances in Engineering and Pure Sciences, 33(4), 687-693.
İrem KALE, T. Didem ALTUN (2022): Tasarım Sürecinde Biyolojik İş Birlikleri: Mikrobiyal Selülozdan Maske Üretimi Üzerine Bir Deneme, Tekstil ve Mühendis, 29: 126, 96-105.
Karakan, G. (2009). Teknik tekstillerin koruyucu yapılarda kullanımı. Tekstil Teknolojileri Elektronik Dergisi, 3(1), 65-70.
Kertmen, M., Karagöl, H., Olucak, H. İ., Pektaş, E. A., Şen, A., & Helvacı, A. R. (2022). Medikal Tekstillerde Kullanılmak Üzere Örme ve Dokuma Kumaş Geliştirilmesi. Uluslararası Bilim Teknoloji ve Tasarım Dergisi, 3(1), 82-98.
Lindemann, B. (2000). Durable antimicrobial effects on textiles. Melliand Textilberichte International Textile Reports, 81(10), E-205.
Mecarcıöz, S., Mecarcıöz, S., Oğulata, T.R., (2011). Teknik Tekstiller-Otobüs Koltuk Döşemelerinde Kullanımı ve Uygulanan Test Yöntemleri. Tekstil ve Mühendis, 18(82), 36-41.

Mecit, D., Başal, G., Ilgaz, S., Gülümser, T., Duran, D., Tarakçıoğlu, I. (2007). Teknik Tekstiller ve Kullanım Alanları (Bölüm 1). Tekstil ve Konfeksiyon Dergisi, (17)2, 79-82.
Mirasoğlu, B., (2024, December 12). Yara Örtüleri ve Pansuman. https://www.klimik.org.tr/wp-content/uploads/2014/06/2.-Uzm.-Dr.-Beng%C3%BCsu-M%C4%B0RASO%C4%9ELU.pdf
Mucha, H., Hofer, D., Assfalg, S., & Swerev, M. (2002). Antimicrobial finishes and modifications. Melliand Textilberichte International Textile Reports, 83(4), 238-243.
Nematpour, N., Farhadian, N., Ebrahimi, K.S., Arkan, E., Seyedi, F., Khaledian, S., Shahlaei, M., Moradi, S., (2020). Sustained Release Nanofibrous Composite Patch for Transdermal Antibiotic Delivery. Colloids and Surfaces A: Physicochemical and Engineering Aspects, 586, 124267.
Orhan, M., Koç, S., Özakın, C., Hocekenberger, A., & Sınırtaş, M. (2019). Hastanelerde Kullanılan Tekstillerin Antibakteriyel ve Anti-mantar Etkinliklerinin Değerlendirilmesi. Kahramanmaraş Sütçü İmam Üniversitesi Mühendislik Bilimleri Dergisi, 22(1), 19-31.
Öncü, G.,& Kaygusuz, M. (2023). Tıbbi Tekstil Atıkları ve Sürdürülebilirlik Çalışmaları 2nd International Conference on Engineering, Natural and Social Sciences, April 4-6, Konya.
Pamuk, O., & Öndoğan, Z. (2008). Cerrahi Personelin Ameliyat Önlükleri İle İlgili Görüşlerinin Belirlenmesi Üzerine Bir Araştırma. Journal of Textile & Apparel/Tekstil ve Konfeksiyon, 18(2).
Pektaş, K., (2024). Çözelti Üfleme Tekniği Kullanılarak Yapısında Sabit Yağ Karışımı İçeren Nanolif Çekimi ve Medikal Tekstil Yüzeyi Eldesi. Kahramanmaraş Sütçü İmam Üniversitesi Fen Bilimleri Enstitüsü Tekstil Mühendisliği Anabilim Dalı, Doktora Tezi, 198s, Kahramanmaraş.
Rošic, R., Kocbek, P., Pelipenko, J., Kristl, J., & Baumgartner, S. (2013). Nanofibers and their biomedical use. Acta pharmaceutica, 63(3), 295-304.
Rowell, R. (Ed.). (2012). Modified cellulosics. Elsevier.
Salani, M., Roy, S., & Fissell IV, W. H. (2018). Innovations in wearable and implantable artificial kidneys. American Journal of Kidney Diseases, 72(5), 745-751.
Sarı, Ç., (2020). Antibakteriyel Ajan İçeren B-Siklodekstrin Kompleksinin ve Türevinin Pamuklu Kumaşlara Uygulanması ve Karakterize Edilmesi. Pamukkale Üniversitesi Fen Bilimleri Enstitüsü Tekstil Mühendisliği Anabilim Dalı, Yüksek Lisans Tezi, 142s, Denizli.
Seong, H. S., Kim, J. P., & Ko, S. W. (1999). Preparing chito-oligosaccharides as antimicrobial agents for cotton. Textile Research Journal, 69(7), 483-488.
Service, D., (1998). Amicor-Antimicrobials Fibers, Chemical Fibers International, 48(6), 486-489.
Seventekin, N., Öktem, T., Tekeoğlu, S. (2001). Tekstilde Antimikrobiyel Madde Kullanımı, Tekstil ve Konfeksiyon, 4:217-224.
Snari, R. M., Bayazeed, A., Ibarhiam, S. F., Alnoman, R. B., Attar, R., Abumelha, H. M., & El-Metwaly, N. M. (2022). Solution blowing spinning of polylactate/polyvinyl alcohol/ZnO nanocomposite toward green and sustainable preparation of wound dressing nanofibrous films. Microscopy Research and Technique, 85(12), 3860–3870.
Souto, E. B., Ribeiro, A. F., Ferreira, M. I., Teixeira, M. C., Shimojo, A. A., Soriano, J. L., ... & Santini, A. (2020). New nanotechnologies for the treatment and repair of skin burns infections. International journal of molecular sciences, 21(2), 393.
Thiry, M.C., (2001). Small Game Hunting: Antimicrobials Take the Field. AATCC Review, November, 11(1), 11-17.
Üreyen M.E., Çavdar A. Koparall, A. S., & Doğan, A. (2008), "Yeni Geliştirilen Gümüş Katkılı Antimikrobiyal Tekstil Kimyasalı ve Bu Kimyasal ile İşlem Görmüş Kumaşların Antibakteriyel Performansları", The Journal of Textiles and Engineer, 15(69), 25-31.
Xia, L., Lu, L., Liang, Y., & Cheng, B. (2019). Fabrication of centrifugally spun prepared poly(lactic acid)/gelatin/ciprofloxacin nanofibers for antimicrobial wound dressing. RSC Advances, 9(61).
Zhumagaziyeva, A. (2021). Nanotekstiller ve Medikal Alandaki Uygulamaları. Mimar Sinan Güzel Sanatlar Üniversitesi, Güzel Sanatlar Enstitüsü, Tekstil ve Moda Tasarımı Ana Sanat Dalı, Tekstil ve Moda Tasarımı Programı, Sanatta Yeterlilik Tezi, 158 s, İstanbul.