

APPLICATION OF TECHNICAL TEXTILE IN MEDICINE

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Abstract: Medical textile is an extremely important subcategory of technical textile because it is covering a wide range of products. The term medical textile itself covers all types of textile materials that are used in the healthcare system for various purposes. Medical textile is also known as health textile and is one of the fastest growing sectors in the technical textile market. The growth rate of technical textiles in this area is due to constant improvements and innovations in both areas: textile technologies and medical procedures. Textile structures used in this field include yarns, woven, knitted and non - woven textile materials as well as composite materials reinforced with textiles. The number of applications is large and diverse, from simple surgical sutures to complex composite structures for bone and tissue replacement, hygiene materials, protective products used in operating rooms and in the process of postoperative wound treatment. The purpose of this paper is to emphasize the importance of technical textiles for medical, surgical and healthcare applications, to indicate which textiles are currently used in this field.

Keywords: textile structure, implantable materials, non-implantable materials, healthcare and hygiene, medical products.

PRIMENA TEHNIČKOG TEKSTILA U MEDICINI

Apstrakt: Medicinski tekstil je izuzetno važna potkategorija tehničkog tekstila jer pokriva širok spektar proizvoda. Sam pojam medicinski tekstil obuhvata sve vrste tekstilnih materijala koji se koriste u zdravstvenom sistemu u različite svrhe. Medicinski tekstil je poznat i kao zdravstveni tekstil i jedan je od najbrže rastućih sektora na tržištu tehničkog tekstila. Stopa rasta tehničkog tekstila u ovoj oblasti rezultat je stalnih poboljšanja i inovacija u obe oblasti: tekstilne tehnologije i medicinski postupci. Tekstilni materijali koje se koriste u ovoj oblasti uključuju pređe, tkanine, pletenine i netkani tekstil kao i kompozitni materijali ojačani tekstilom. Postoje mnogo raznovrsne mogućnosti primene medicinskog tekstila, od jednostavnih hirurških šavova do složenih kompozitnih struktura za zamenu kostiju i tkiva, higijenskih materijala, zaštitnih proizvoda koji se koriste u operacionim salama i u procesu tretmana postoperativne rane. Svrha ovog rada je da naglasi važnost tehničkog tekstila za medicinske, hirurške i zdravstvene usluge, da ukaže koji se tekstil trenutno koristi u ovoj oblasti.

Ključne reči: tekstilni materijali, implantabilni materijali, neimplantabilni materijali, zdravstvena nega i higijena, medicinski proizvodi.

1. INTRODUCTION

The term technical textiles includes all textile-based products used primarily for their performance or functional characteristics, not for their aesthetic and decorative properties. This means that technical textile is designed to feature wide spectrum

of certain characteristics, making them suitable for application in extensive range of industries (automotive, aerospace, construction, protective gear, healthcare, and others). Depending on their purpose, these textiles are designed to have improved filtration, flexibility, durability, lightness, resistance and strength properties, amongst other features [1, 2].

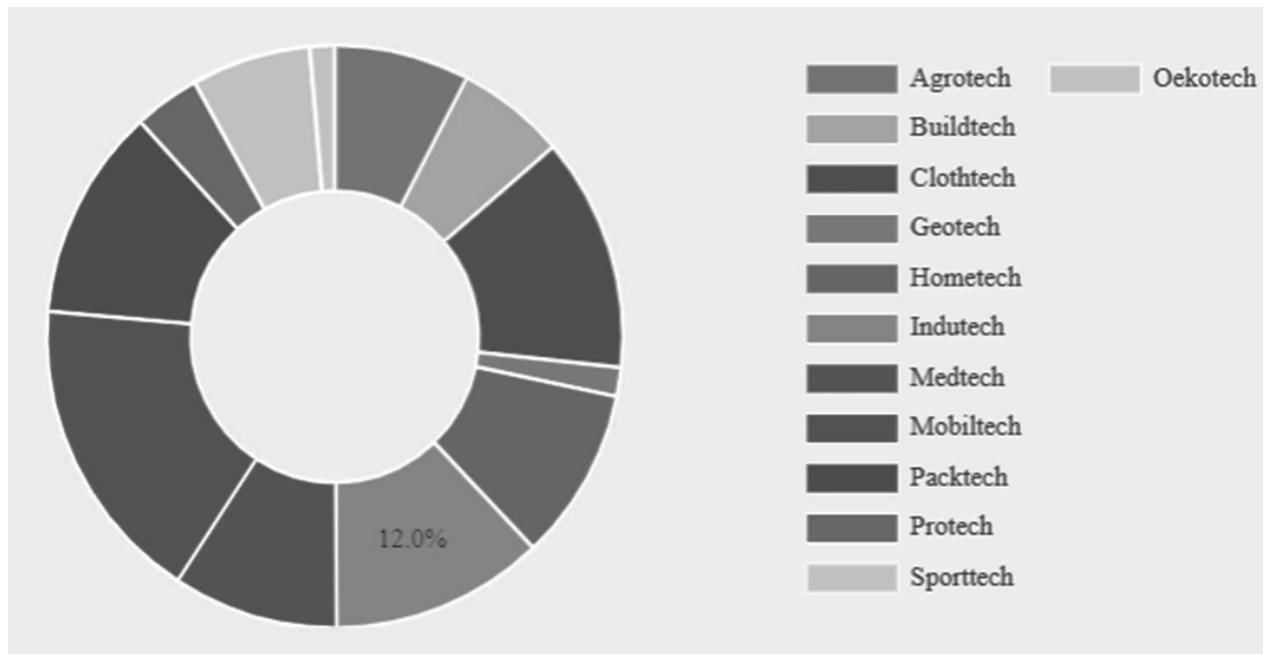


Figure 1: Global technical textiles market share, by product type, 2018 [4]

Technical textile products are usually classified into twelve groups, based on application and end-user industry, and is mainly comprised of (Figure 1): agro textiles (agrotech), construction textiles (buildtech), clothing textiles (clothtech), geo-textiles (geotech), domestic textiles (hometech), industrial textiles (indutech), medical textiles (meditech), textiles used in transport (mobiltech), packaging textiles (packtech), protective textiles (protech), sports textiles (sportech) and environmentally-friendly textiles (oekotech) [3,4].

Technical textiles are considered to be the fastest growing sector of the textile industrial sector. The production of technical textiles makes up more than half of the production of textiles because the number of technical applications is significantly higher than the textile applications. The current volume market worldwide for technical textile is 193.9 billion in US dollars, and it's projected to reach \$220.37 billion by 2022 at CAGR 5.89%. In terms of volume, this market was projected to reach 42.20 million metric tons by the end of 2020, growing at a rate of around 4.68% [5]. Technical textile industry has witnessed remarkable growth in the past few years and this growth is estimated to increase in the next years.

Medical textiles is one of the most dynamically expanding and growing field in technical textiles [6]. An important and larger part of the products of the textile industry are used in the medical, health and hygiene sectors. The number of applications is large and diverse, from simple surgical sutures to complex composite structures for bone and tissue replace-

ment, hygiene materials, protective products used in operating rooms and in the process of postoperative wound treatment. The degree of growth and application of technical textiles in this area is due to constant improvements and innovations in both areas: textile technologies and medical procedures. The healthcare and medical sectors offer the greatest opportunities for the development of the most sophisticated and valuable textile materials for different types of medical applications and represent one of the most important areas for stimulating production of technical textiles [7, 8].

2. TEXTILE INTENDED FOR MEDICAL AND HEALTH CARE

The term medical textile covers all types of textile structures that are used in the healthcare system for various purposes. The textile structures used include yarns (monofilament and multifilament), woven, knitted, braided and non-woven textile materials as well as textile reinforced composite materials.

The history of medical textiles goes back to thousands of years ago when the development of wound closures and sutures took place, but the "official" application began with the development of medical services [9]. With the development of new types of fibres and technologies for the production of linear and two dimensional textile structure, the application of textile materials for medical purposes is even more significant. Depending on the application of medical textiles, an appropriate choice of constituent

elements can be made, starting from the type of polymers and fibres to the shape of the textile structure and the type of textile material. Textile fibres used for medical purposes differ from other conventional materials because they must meet certain standards and criteria, as follows [10]:

- Not to have toxic effects on the human body;
- Do not cause skin irritation or allergic reactions;
- Adequate mechanical properties (strength, elasticity, durability and etc.);
- Good absorption of moisture and water;
- Good air permeability;
- Biocompatibility;
- Bacteriostaticity;
- Antiviral properties;
- Ability to be sterilized;

The major requirements of textile material used in medical are absorbency, tenacity, flexibility, softness and biostability or biodegradability. By using suitable polymers in the production of textile fibers and materials the above requirements can be met. Different types of fibers obtained from natural and manufactured polymers can be used for the production of this type of textile materials. The most commonly used

polymer fibrous materials for production of medical textiles are given in Table 1 [11, 12].

3. CLASSIFICATION OF MEDICAL TEXTILE

Medical textiles are an extremely important sub-category of technical textiles because they cover a wide range of products. Mainly four type of textile structures are used for production of medical textile products. These are woven, knitted, braided and non-woven. The first three of these are made from yarns, whereas the fourth can be made directly from fibers, or even from polymers. Yarns are interlaced into fabrics by different mechanical processes (weaving, knitting and braiding). The characteristics and properties of each textile structure determine its suitability for a particular application. Woven fabrics are usually dimensionally very stable but less extensible and porous than other structures. The major advantage of knitted fabrics is their flexibility and inherent ability to resist unraveling when cut. A potential limitation of knitted fabrics is their high porosity. Braided structures can be designed using several different patterns, either with or without a core, and they are usually used for production of biodegradable and non-biodegradable surgical sutures, artificial ligament, artificial tendon, etc.

Table 1: Types of polymers for production of medical textile [11,12]

Types	Origin	Fibers and polymers
Natural fibers	Vegetable (cellulose)	Cotton Linen Hemp
	Animal (protein)	Silk
Man made fibers	Artificial (by transformation of natural polymers)	Regenerated cellulose (viscose, lyocell) Proteins (collagen) Alginate fiber Chitin Chitosan Polylactide fiber Polyglycolide fiber
	Synthetic (from synthetic polymers)	Polyamide Polyester Polypropylene Polyurethane Polytetrafluoroethylene
	Inorganic (from inorganic materials)	Carbon Glass Metal

Non-woven textile materials have the greatest application for the production of medical textiles because they can produce disposable and cost effective products [13]. The properties of nonwoven fabrics depend on the characteristics of the constituent polymer or fiber and on the bonding process. There are numerous medical uses for nonwoven fabrics: bandages, absorbent pad, wipes, gowns, surgical caps and mask, etc. Analyzes show that nonwovens accounted for 64.29% of the global medical textile market in 2018 and is projected to grow at a fastest CAGR of 5.0% during the forecast period (2015-2025). The second largest segment is woven fabrics with 15.38% of global market volume in 2018 and is projected to

reach 491.8 kilo tons by 2025 (Figure 2). Woven fabrics typically find their applications in hospital and surgical hosiery, different types of bandages, wound contact layer, plasters, artificial tendons, cardiovascular implants, etc. Knitted fabrics are used for cardiovascular implants and other applications used in surgical mesh, hernia repair, reconstructive and cosmetic surgery mesh and various other containment devices [14].

Also, another feature of the medical textile market is the growing proportion of textile-reinforced composite materials used in wound management products. This will mean the combination of textiles with such materials as films, foam and adhesives to form

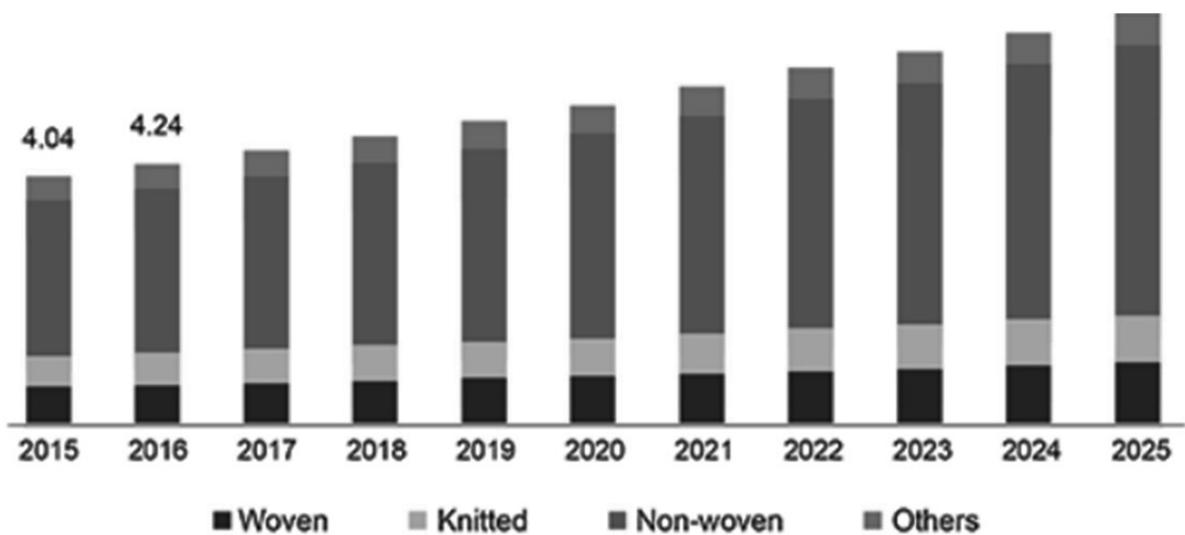


Figure 2: U.S. medical textile market, size by type of textile material, 2015-2025 (billion USD) [14]

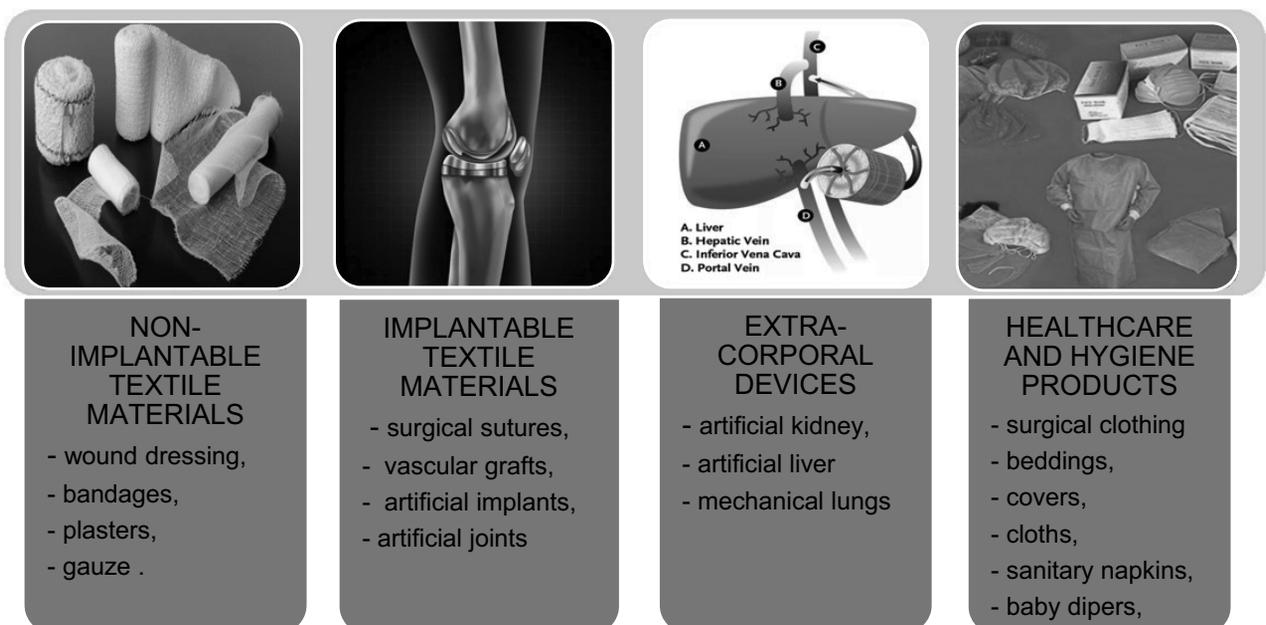


Figure 3: Classification of medical textile by application [15, 16]

structures for the treatment of wound and healthcare products.

Textile materials are used in a number of separate and specialized applications which can be categorized into 4 main areas of application (Figure 3): non – implantable materials, implantable materials, extracorporeal devices and healthcare and hygiene products [15,16].

3.1. Non-implantable textile materials

Non-implantable materials are used for external applications on the body, they are never implanted

within the body. The function of these materials is to provide protection against infection, to absorb blood and body secretions, and in certain cases for use of medicaments in postoperative treatments etc. [17]. This type of material can, but does not have to be in contact with the skin. Some examples of non-implantable materials include wound care, bandages, plasters, orthopedic belts, pressure garments, etc. (Table 2). For production of these type of materials can be used different kind of textile fibers: cotton, silk, viscose, lyocell, collagen, polyester, polyamide, polypropylene etc.

Table 2: Types of fibers for non-implantable medical textiles and their application [16]

Types of fibers	Types of textile materials	Application, products
Cotton, viscose, lyocell	Non-woven	Absorbent pad
Alginate fiber, chitosan, silk, viscose, lyocell, cotton	Woven, non-woven, knitted	Wound-contact layer
Cotton, viscose, lyocell, polyamide fiber	Woven, non-woven	Base material
Cotton, viscose, lyocell, elastomeric fiber yarns	Woven, knitted, non-woven	Simple non-elastic and elastic bandages
Cotton, viscose, lyocell, elastomeric fiber yarns	Woven, knitted, non-woven	High support bandages
Cotton, viscose, lyocell, Polyester, elastomeric fiber yarns	Woven, knitted	Compression bandages
Cotton, viscose, lyocell, polyester, polyurethane foam	Woven, non-woven	Orthopedic bandages
Cotton, viscose, lyocell, polypropylene, polyester,	Woven, knitted, non-woven	Plasters
Cotton, viscose, lyocell, alginate fiber, chitosan	Woven, knitted, non-woven	Gauze dressing
Cotton	Woven fabrics	Lint
Viscose, cotton linters, wood pulp	Non-woven	Wadding
Poly lactide, polyglycolide, carbon fiber	Needle punched non-woven	Scaffold

3.2. Implantable textile materials

Implantable materials are biocompatible and are used in effecting repair to the body whether it is wound closure (surgical sutures) or replacement surgery (soft tissue implants, orthopedic implants, cardiovascular implants). The soft-tissue implants

are flexible strong materials commonly used to replace tendons, ligaments and cartilage in both reconstructive and corrective surgery [18]. In Table 3 are presented textile fibres and fabrics used for the implantable materials, and some of the areas of their application [16].

Table 3: Types of fibres for implantable medical textiles and their application [16]

Types of fibres	Types of textile materials	Application
Surgical sutures		
Collagen, polylactide, polyglycolide	Monofilaments, braided	Biodegradable surgical sutures
Polyester, polyamide, polypropylene, polyethylene, polytetrafluoroethylene	Monofilaments, braided	Non-biodegradable surgical sutures
Soft tissue implants		
Polytetrafluoroethylene, polyethylene, Polyester, polyamide, silk	Woven, braided	Artificial tendon
Polyester, carbon, collagen	Braided	Artificial ligament
Low-density polyethylene	Non-woven	Artificial cartilage
Chitin	Non-woven	Artificial skin
Polymethyl methacrylate, silicon fibre, collagen		Eye contact lenses
Orthopedic implants		
Silicone, polyacetyl fibre, polyethylene fibre		Artificial joints/bones
Cardiovascular implants		
Polyester, polytetrafluoroethylene	Knitted, woven	Vascular grafts
Polyester	Knitted, woven	Heart valves

Table 4: Types of extra-corporeal devices [15]

Types of fibers	Application	Function
Hollow viscose	Artificial kidney	Remove waste products from patients' blood
Hollow viscose	Artificial liver	Separate and dispose of patients' plasma and supply fresh plasma
Hollow polypropylene fiber, Hollow silicon membrane	Mechanical lung	Remove carbon dioxide from patients' blood and supplying fresh oxygen

3.3. Extra-corporeal devices

Extra corporal devices are mechanical organs used to support the function of vital organs (kidney, liver, lung etc.). These devices are used for blood purification such as hemodialysis, hemofiltration, plasma-exchange and hemoabsorption. In Table 4 are presented the types of extracorporeal devices, fibers used for their production and their function.

3.4. Healthcare and hygiene products

An important area of medical textile is the healthcare and hygiene sector. They cover all those

materials that are used for external application, protection and safety of the medical staff and patients. They are designed to either be washable or discarded after a single use. All fibers used in this product must be non-toxic, non-allergenic, noncarcinogenic and must be able to be sterilised without imparting any change in their physical or chemical characteristics [19]. Healthcare and hygiene products include (Table 5): hospital gowns and uniforms, clothing and wipes, surgical hosiery, masks, caps, hospital bed products etc.

Table 5: Types of products for health protection and hygiene maintenance [15]

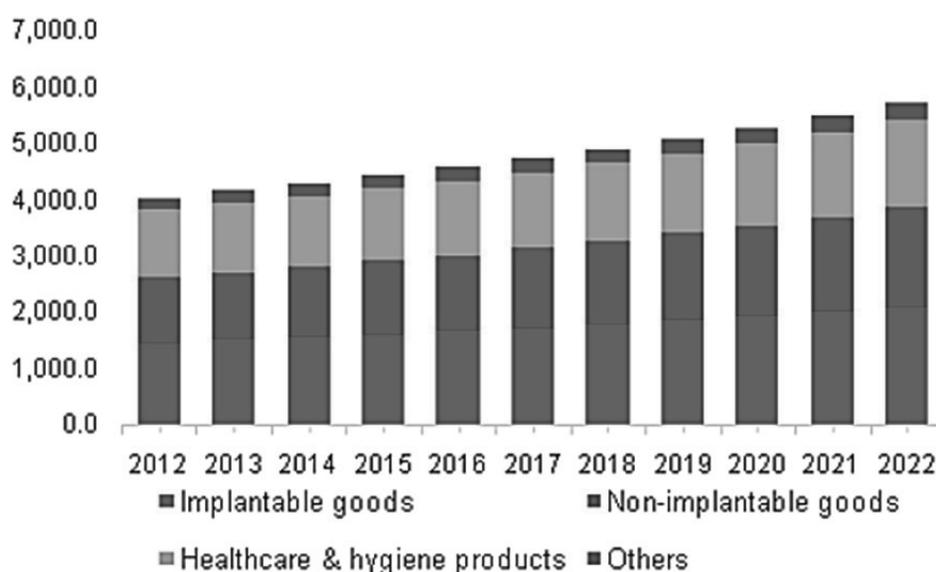
Types of fibers	Types of textile materials	Application of the product
Cotton, polyester, polypropylene	Non-woven, woven	Surgical gowns
Viscose	Non-woven	Surgical caps
Viscose, polyester, glass fiber	Non-woven	Surgical masks
Polyester, polyethylene	Non-woven, woven	Surgical drapes and cloths
Cotton, polyester, polyamide	Knitted	Surgical hosiery
Cotton, polyester	Woven, knitted	Blankets
Cotton	Woven	Sheets, Pillow cases
Cotton, polyester,	Woven	Uniforms
Polyester, polypropylene	Non-woven	Protective clothing
Super absorbent fibers, wood fluff	Non-woven	Absorbent layer
Polyethylene	Non-woven	Outer Layer
Viscose, lyocell	Non-woven	Cloths, wipes

4. MEDICAL TEXTILES MARKET

The global medical textile market has been segmented into Europe (Germany, UK, France), North America, South America, Asia Pacific (China, Japan, India, South Korea), and the Middle East and Africa. North America collectively lead the medical textiles sector owing to remarkable growth in end-use businesses including Implantable goods and healthcare and hygiene products. Europe holds the second position in the global medical textile market. Asia-Pacific is viewed as a promising market for the global medical textile sector. This is owing to the growing incidence

of diseases, wide-ranging need for innovative medical equipment, increasing application of the initial stages of diagnosis of conditions, and the increasing amount of healthcare centers. Asia-Pacific is expected to represent the fastest growing market for medical smart textiles goods during the forecast period. The Middle East & Africa (MEA) region represents a relatively small share of the global medical textile market, owing to the poor economic conditions and the stringent government policies [19].

The global medical textile market is expected to reach USD 20.23 billion by 2022, according to a new

**Figure 3:** Europe medical textiles market revenue, by application, 2012-2022 (USD Million) [14]

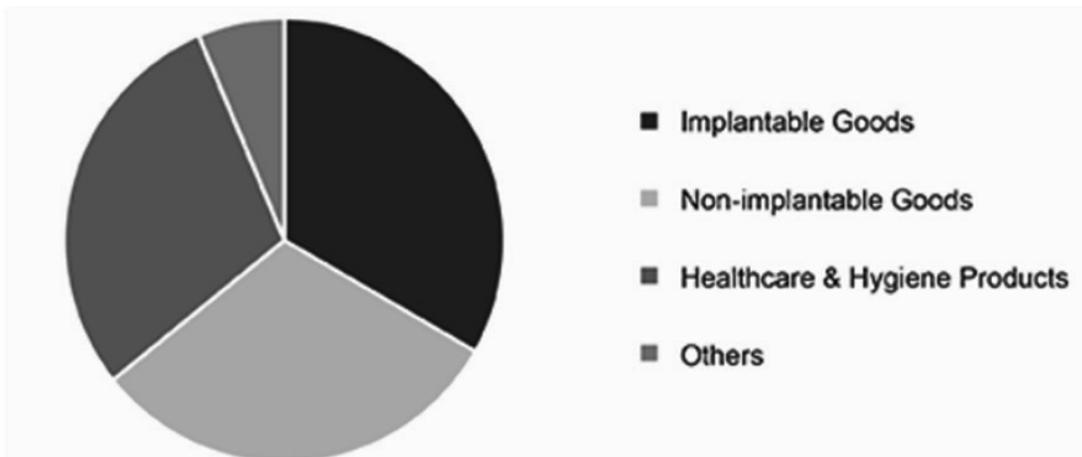


Figure 4: Global medical textiles market share, in terms of revenue, by application, 2018 (%) [14]

report by Grand View Research, Inc. [20]. These predictions are primarily based on the increasing number of elderly population, current technological advancements, increasing health awareness and strict legal regulations that require the use of medical textiles.

In terms of application, in 2018 implantable products had the largest share (33.20%) in global revenues (Figures 3 and 4). The increase in the number of chronic diseases (coronary heart disease, cholesterol and hypertension), is expected to increase the consumption of implantable products. Non-implantable products accounted for 32.24% of the global market volume in 2018.

Although textiles are widely accepted for medical and surgical applications, new areas of application are constantly emerging. Fibre manufacturers produce different types of textile fibres and structures whose properties are adapted to the end application, whether the requirement is absorption, durability, flexibility, softness or biodegradability. Increasing income levels, an ageing population, rising health awareness, increasing disposable income are major factors considered to support the growth of the global medical textile market in the near future. Continued advances in medical science and textile technology, together with change of consumer demands, are expected to contribute to the growth of the medical textile market.

5. CONCLUSION

Medical textiles is one of the most important subcategory of technical textiles because they cover a wide range of products. Ranging from disposable products such as diapers and sanitary pads, various types of towels and wipes, to highly sophisticated or-

gans and devices for blood filtration, prosthetics and orthopedic aids. The main attribute of a medical textile is that it should fulfil the purpose for which it was designed. Successful application of textiles in medicine implies interdisciplinary cooperation between scientists in the field of polymers, textile materials and medicine. With latest innovations in the field of textile technology, a wide variety of non-woven, knitted, and woven forms of the textile are gradually finding their way into a variety of medical procedures. The textile will be used in all extra corporal devices, external or implanted materials, healthcare and hygienic products. There is a dynamic increase in consumption of this type of textile products in the last 30-40 years and this trend is expected to continue in the future. The large number of health problems, the increase of awareness for better health solutions, the increase of available incomes, are expected to increase the demand for medical textiles in the future. In the coming period, a significant increase in demand for medical textiles in the sector of healthcare and hygiene in developing countries is expected. The medical textiles industry continues to grow at an alarming rate, with constant development of new smart technologies. Developments in the fields of the intelligent textile offer new opportunities for creating medical textiles with a higher level of functional characteristics and allow the development of completely new active medical textiles.

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