HEALTHCARE AND HYGIENE PRODUCTS: AN OVERVIEW

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MARKET PROSPECTS

It has been reliably predicted that in 2006 world production of nonwoven fabrics will be 5.14 million tonnes; growth in developed countries will be 5% and that in emerging countries 10-15%, giving an overall figure of 7% per annum. Nonwovens now have a 25% share of the European textile market, with a 5% annual growth and a production of 1.2 million tonnes in 2002(1).

The market share of the individual end product sectors in the European nonwovens industry in 2002 was 33% disposable hygiene products, 16% wipes, 12% buildings and 39% others. Wipes recorded 60% growth between 2000 and 2002.

Sales to US and Canadian end users of converted disposable products will grow in constant dollars from close to $15 billion in 2002 to about $18 billion by 2007.

Consumer end products, including baby diapers and training pants; feminine hygiene items; adult incontinence products; fabric softeners; baby and adult, household and personal care wipers accounted for 78% of 2002 sales; medical and industrial items accounted for 14% and 8% respectively, of those sales(2).

Numerous changes are occurring in the large hygiene absorbent product sector. Priorities for hygiene absorbent products makers include improved leakage prevention, convenient and secure product application, improved wearer comfort and discreet designs that look like underwear. The leakage prevention priority, as an example, requires new fabrics for advanced fluid transport and absorption systems, cloth-like barrier materials and cost-competitive elastic garments(2).

With increasing world population, improved hygiene and healthcare standards, longer life spans, better awareness and higher expectations for physical fitness and increased time available for leisure and hobbies, it is obvious that healthcare and hygiene products will not only grow in volume but will also become more sophisticated and smart or intelligent, with built-in performance indicators and warnings for disposal or change. More and more of such products will incorporate microprocessors or piezo electrics as part of their functionality or performance.

CURRENT ISSUES

A number of crucial issues regarding medical products in general and healthcare and hygiene products in particular have been identified and debated amongst clinicians, environmentalists, drug companies etc for a long time now. The issues such as natural against chemical or manufactured fibres; disposables against reusable or durable fabrics; antibacterial or antimicrobial fibres against such finishes or coatings for infection control; and method of disposal of clinical waste i.e. landfills against incineration and other forms of medical and clinical waste disposal, are constantly being discussed in most relevant forums and conferences across the globe.

One thing is certain that infection control both within the hospital and in the household environments has become an extremely serious concern to everyone, as some 5000 deaths are caused as a direct result of unhygienic hospital environments in the UK every year. The control of micro-organisms, including Ecoli, Staph aureus MRSA, Enterococcus faecium VRE and SARS etc has become an international issue of great importance and concern.

There is a general move towards an increased use of natural polymers that are biocompatible, biodegradable and non-toxic.

HEATHCARE AND HYGIENE PRODUCTS

A number of reviews on medical textiles have been published, which have covered the various healthcare and hygiene products in common use, either within the hospital or can be purchased at the chemist or across the counter in a store. The reader is referred to a number of publications on this topic area (3), (4), (5), (6), (7) and (8).

Recent advances and future trends in some of such products are briefly covered in this overview, and recent developments in some of these products are also covered in the subsequent papers included in this chapter.

SUPERABSORBENT FIBRES

Superabsorbent fibres absorb up to 50 times their mass of water, whereas the conventional wood-pulp and cotton-filler absorbents absorb approximately 6 times their mass. The SA fibres offer advantages as compared to SA powders due to their physical form, or dimensions, rather than their chemical structure. Whilst they do absorb fluids to a similar level as powders, they do, however, do it faster. This is due to the small diameter of the fibres ($\approx 30\mu$), which gives a very high surface area for contact with the fluid. Typically the fibre will absorb 95% of its ultimate capacity in 15 seconds.

Another advantage of using SA fibres as against the powders is that the fibre does not lose its fibrous structure upon absorption of fluids. When the fibres are allowed to dry out they return to their original form and are still absorbent(9). A number of such fibres are commercially available, such as Acordis's Oasis and Camelot's Fibresorb.

ANTIMICROBIAL FIBRES

It has already been mentioned earlier that microbial contamination in the hospital and household environments has become a serious threat to the human life and safety. Resistant strains and superbugs, such as MRSA, contagious risks in healthcare environments, odours in elderly care homes, maintenance of medical instruments etc have been identified as risks that can cause deaths of patients, while they receive treatment for their illness or injuries.

Antimicrobial agents can either be incorporated within the fibre structure, at the spinning stage, or can be applied on the surface of fibres, yarns or fabrics as a finish or coating after the substrate has been produced. Both techniques are currently used depending upon the type of product and its intended application.

Antibacterial polyester(6) or polyamide fabrics have recently been developed by introducing antibacterial agents into the fibre structure rather than depositing them on their surface for longer durability and effect.

Both alginate and chitosan fibres are known to possess antimicrobial properties. In alginate fibres, when fluid is absorbed into the wound dressing, the calcium ions in the fibres exchange with sodium ions in the fluid, and the fibres are transformed from water insoluble calcium alginate into water soluble sodium alginate, resulting in the absorption of a large amount of water by the fibres. In the fabric form, such as a nonwoven structure, as the fibres absorb water and swell, the spaces between the fibres are closed and any bacteria carried in the fluid are trapped in the fibre. This can help reduce the spreading of bacteria.

As a polymeric amine, chitosan is positively charged when wet. Because the cell walls of the bacteria are negatively charged, they adhere to the chitosan fibres. Due to the different electric charge, the bacteria cell walls can burst, resulting in the containment of the bacteria.

It should be pointed out that although alginate and chitosan fibres have some antimicrobial effects, their effectiveness in killing bacteria is limited. Latterly, attempts have been made to introduce silver ions, in various forms, into the alginate and chitosan fibres, thus making them more effective as antimicrobial fibres(10).

A synergistic system of a formulation consisting of inorganic chemicals involving a metal salt of a monocarboxylic acid, a carbamic acid derivative, a chealating agent, a boron compound, a dimethylene siloxane derivative and an alkane polymer has been proved to serve as an effective antimicrobial agent in arresting the growth of several bacteria (Gram-positive and Gram-negative), fungi and mildew on 100 per cent cotton woven fabrics, when treated with the above formulation. The effect is said to be 100 per cent up to 50 launderings and the treatment also prevents the deterioration of the fabrics by micro-organisms(11).

A number of proprietary chemical formulations are now available as microbial control systems for healthcare and hygiene products, such as Byotrol(12) and Amicor Plus Technology(13).

DISPOSABLE PRODUCTS

Absorbent disposable products, such as diapers, sanitary napkins, tampons, incontinence products, panty shields, wipes, etc are mostly single-use items and are designed to receive, absorb and retain body fluids and solid wastes. The disposable diaper for baby care was first marketed in Sweden in the late 1930s, and the present all-in-one diaper consists of multilayer components with an enhanced facility to collect urine and faecal waste and incorporates a superabsorbent polymer as an absorbent component.

A modern breathable disposable feminine product consists of three layers, of which the inner top layer is made of a blend of hydrophobic, low density fibres and is liquid- and water- permeable. The core layer, packed with wood pulp and other absorbent materials, is highly absorbent and the third layer consists of a multi layer barrier, that is water vapour permeable, but resistant to liquid water.

A modern incontinence product also consists of three layers; a cover stock, that is permeable and diffuses the liquid laterally; a highly absorbent core; and a barrier polyethylene or polyvinyl chloride film that helps the patient, clothes or bedding to keep dry.

It has been mentioned many times in the overview that the argument between disposable and durable hygiene and healthcare products will continue and one obvious solution of this argument is the increased and universal usage of biodegradable natural and manufactured fibres and products across the whole spectrum of products. The recycling or disposal of clinical and medical waste materials poses problems of health and safety and availability and cost of landfill sites and incineration.

OPERATING ROOM GARMENTS

Significant innovation and research and development have been carried out in the area of Operating Room garments (OR garments). Disposable surgical drapes, surgical gowns and staff apparel have been developed as a composite of hydroentangled polypropylene face fabric laminated to a microporous breathable film which acts as a barrier to most types of micro-organisms and viruses. Some parts of the garments are also reinforced with liquid/blood repellent layers that are detachable after the operation. Durable or reusable OR garments are also popular in a number of countries, which consist of 100 per cent woven staple-fibre or continuous-filament polyester fabric coated with P.T.F.E. or laminated to a P.T.F.E. film. Some surgeons prefer 100% cotton or polyester/cotton plain woven fabrics coated with or laminated to a microporous breathable coating or film.

Surgical masks, such as Filtron and Aseptex, protect medical and dental professionals from acquiring or transmitting infections.

Conductive shoe covers dissipate static charges and are used in endoscopic, laser and electrical-based surgical work.

SUMMARY

It is obvious that healthcare and hygiene products form an important part of medical textiles and their role and importance keep increasing as the affluence and consumer demands increase to cope with modern living pace and deal with the stresses and strains arising from it.

An example of modern-day living health hazards is the increased risk of contracting Deep Vein Thrombosis (DVT), a venous disorder caused due to long haul flights. Special flight socks made from polyamide and Lycra filament yarns on sophisticated fully electronic half-hose machines with appropriate compression of 17 mmHg at the ankles dropping down to 10 to 12 mmHg at the calf have been designed and developed specifically to counteract this problem. Even thermochromic dyes are being explored to indicate the outset of venous disorder as the skin temperature changes due to swelling or fever.

Many such new and novel products will appear on the market as the modern pace of life hastens even more.

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APPLICATION OF NONWOVENS IN HEALTHCARE AND HYGIENE SECTOR

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ABSTRACT

Medical textile products are based on fabrics of which there are four types : woven, knitted, braided and nonwoven. Depending upon the usage, medical textiles are sub divided into :

- Implantable medical textiles
- Non - Implantable medical textiles
- Extra – Corporeal devices
- Healthcare / Hygiene products.

Nonwovens have, as does no other textile fabric, the potential to be adapted to changing requirements as regards processing and utilization properties. Nonwoven medical products are preferred by many healthcare professionals because of infection, protection advantages, convenience and cost efficiency.

Nonwoven :
A manufactured sheet, web or batt of directionally or randomly orientated fibres, bonded by friction, and / or cohesion and / or adhesion, excluding paper and products which are woven, knitted, tufted, stitch – bonded incorporating binding yarns or filaments, or felted by wet – milling, whether or not additionally needled.

The fibres may be of natural or manufactured. They may be staple or continuous filaments or be formed in situ.

In 1999, the world production of nonwovens reached 2.5 million tons valued US$ 10 billion. Preliminary projection for 2004 for world consumption of hygiene absorbent products is 311 billion units. Penetration of the theoretically available global market is only 15% for diapers, under 30% for feminine pads and under 10% for adult pads. Feminine hygiene products accounted for 62% of total unit volume, baby diaper and training pants 33% and adult incontinence products the remainder. Nonwovens are used in hygiene absorbent products in so-called "Cover Stock" applications (top sheet, leg cuff fabric, back sheet, and other uses), as acquisition / distribution layers and in preformed absorbent cores.

End use product markets for medical nonwovens include surgical packs, pants and gowns, accessory operating theatre apparel (caps, masks, shoe covers and related), sponges and bandages (so – called gauze replacement), sterilization wrap (CSR wrap) and a number of other products.

Until now, nonwovens have only been made from staple fibre, Sandler has now produced nonwovens directly from granulated polymer for hygiene under trade name of Sawascreen", which are also antimicrobial finished.

The targeted selection of raw materials and the combination of different web forming and bonding process of nonwovens provides for a composite construction in line with functional requirements. For nonwovens therefore, there are excellent future prospects which can be further extended by process and product innovations.

INTRODUCTION

Textiles come to our help in every walk of life. Today, traditional textiles are unable to cope with high cost of production and modernisation as well as rapid obsolescence. Textiles are no more restricted for apparel use only. Technical Textiles have establised strong potential to offer an opportunity for revival of the industry[10]. The fields of application of technical textiles are unlimited and the ideas often revolutionary. Technical Textiles are basically products which, in the widest sense, are used not just for classic clothing[8]. Various user branches have been identified and defined a total of 12 fields of application of technical textile[36].

MEDICAL TEXTILES

Textile products for medical applications include such materials as fibres, yarns[2], woven and knitted fabrics and PTFE felt and mesh[1], non-wovens[2], etc.

Manufacturing medical fabrics

Medical textile products are based on fabrics, of which there are four types: woven, knitted, braided and nonwoven .

Depending upon the usage, medical textiles subdivided into :
Implantable medical textiles
Non-implantable medical textiles
Extra-corporeal devices
Healthcare / Hygiene products[2,35]

HEALTHCARE AND HYGIENE SECTOR

An important area of textile is the healthcare and hygiene sector among other medical applications. The range of products available for healthcare and hygiene is vast, but they are typically used either in the operating theatre or in the hospital wards for hygiene, care and safety of the staff and patients. They could be washable or disposable. Table 1 shows in general the traditionally existing range of products available in the healthcare textiles, the fibre used in their manufacture and the method of manufacturing[26,27,28,33,37].

What are non wovens ?

Nonwoven: A manufactured sheet, web or batt of directionally or randomly oriented fibres, bonded by friction, and / or cohesion and / or adhesion, excluding paper and products which are woven, knitted, tufted, stitch-bonded incorporating binding yarns or filaments, or felted by wet-milling, whether or not additionally needled.
The fibres may be of natural or man-made origin. They may be staple or continuous filaments or be formed in situ[3,4].

TABLE 1 : HEALTHCARE / HYGIENE PRODUCTS

Product Application	Fibre Type	Fabric Type
1. Surgical Clothing		
Gowns	Cotton, Polyester Fibre, Viscose, Polypropylene Fibre	Non-woven, Woven
Caps	Viscose	Non-woven
Masks	Polyester Fibre, Viscose, Glass	Non-woven
2. Surgical Covers		
Drapes	Polyester Fibre, Polyethylene Fibre	Non-woven, Woven
Cloths	Polyester Fibre, Polyethylene Fibre	Non-woven, Woven
3. Beddings		
Blankets	Cotton, Polyester	Woven, Kintted
Sheets	Cotton	Woven
Pillow Covers	Cotton	Woven
4. Clothing		
Uniforms	Cotton, Polyester	Woven
Protective Clothing	Polyester, Polypropylene	Non-woven
5. Incontinence Diaper / Sheet		
Coverstock	Polyester, Polypropylene	Non-woven
Absorbent Layer	Wood Fluff, Super absorbents	Non-woven
Outer Layer	Polyethylene Fibre	Non-woven
6. Cloths / Wipes	Viscose	Non-woven
7. Surgical Hosiery	Polyamide, Polyester, Cotton, Elastomeric yarns.	Knitted

CONSUMPTION OF NONWOVENS

The market is quite large, of the order of 5.5 billion square yards of nonwovens per year worldwide. In 1999, the world production of nonwovens reached 2.5 million tons, valued US$ 10 billion[11]. The consumption of nonwoven in medical application in the developed markets in 1999 was the equivalent to USD 0.83 billion and consumption is expected to grow to USD 1.03 billion by 2004. In contrast, in the developing markets, hygiene nonwovens consumption in 1999 was the equivalent to USD 0.87 billion and consumption is expected to grow at 11% per year to USD 1.48 billion by 2004[32]. The consumption of medical nonwovens in the developing markets was only U.S.$ 0.05 billion. Consumption is expected to grow at 22% per to U.S.$ 0.14 billion by 2004. The developing market regions of the world continue to be the primary source of volume growth for absorbent products, especially baby diapers, because the mature markets of North America, Canada, Western Europe and Japan have been already highly penetrated[21].

HYGIENE

Preliminary projection for 2004 for world consumption of hygiene absorbent products is 311 billion units. Penetration of the theoretically available global market is only 15% for diapers, under 30% for feminine pads and under 10% for adult pads. Feminine hygiene products accounted for 62% of total unit volume, baby diaper and training pants 33% and adult incontinence products the remainder. Cover stock consumption, globally, is over 33 billion m^2.

MEDICAL

When considering medical products which contain nonwovens, an understanding of the fabric technologies and specific challenges of the individual end uses is essential. Frequently, the medical fabrics market place is considered as servicing one particular need, that of a "barrier"[12, 17, 5].

In general, medical textile products can be classified into three basic categories :

Patient Specific

Sponges, tapes, burn sheets & other types of wound dressings, the nonwoven accounts for only about 20% of the cost of the product, which is frequently a composite construction.

General Patient Management Products

Underpads, adult diapers and wipes. Nonwovens represents about 25% of the final product sales and is also a primary composite construction.

Procedure Specific Products

Is the single largest segment and includes sterilization wrap, surgical gowns, drapes, table covers, face masks, head and shoe-covers. Here nonwoven fabric basically is the product and represents more than 60% of the product cost[22].

The advantages offered by a nonwoven product depend on end use and the competing product (Table 2)[29].

Major segments

Sterilization wrap, sterile surgical gowns, drapes and surgical packs are the principal products representing about 60% of the total nonwovens yardage used[12].

Sterilization Wrap

Single-use sterilization wraps, also called CSR (Central Supply Room) wraps are sold as flat sheets cut to specific sizes. The use is primary for wrapping trays and large instruments in the hospital central supply room, in preparation for sterilization in a steam autoclave,

Table 2:Advantages of Non wovens

	Compete with	Nonwoven Advantage
Drapes	Woven fabric	Cost
Surgical Wear	Woven fabric	Reduced infection
Wipes	Paper	Durability, less lint

ethylene oxide chamber or plasma sterilizer. Critical performance feature includes tensile strength, tear and abrasion resistance, and high filtration efficiency in the 3-5 micron range (bacteria and dust particles).

Gowns and Drapes
Are sold as "Sterile Products" because they are provided to hospitals in a sterilized package, having been pre-sterilized by the manufacturer, generally by ethylene oxide or Cobalt 60 irradiation. Gowns may be reinforced or unreinforced. These refers to lining the so-called target zones-sleeves from wrists-to-elbow and chest-to-abdomen areas-with either a second layer of the base fabric or a layer of film. Performance features are tear resistance, fluid barrier, abrasion resistance and breathability.

Drapes are sold as flat folded sheets with film backing in most cases. Surgical drapes are used in the operating room to cover patients and cover cloths are used to cover area around patient. Nonwovens are used as backing material on one or both sides of a film, which is impermeable to bacteria. Nonwoven backing is highly absorbent to both body perspiration and secretions from the wound. Hydrophobic finishes may also be used as bacteria barrier.

Surgical masks are made of three layers : a middle layer of extra fine glass fibres or synthetic microfibres covered on both sides by acrylic bonded parallel-laid or wet laid nonwoven. Performance requirement : high bacterial filtration capacity, high air permeability, light weight and non-allergenic[30].

DESIGN ISSUES

The main issue in the design and use of operating room fabrics used to be protection of the patient from contamination by the environment and by healthcare workers as well as the preservation of sterility of the instruments used in invasive procedures. With escalating concerns over AIDS and hepatitis and now very recently SARS, the requirement for protecting healthcare workers has been raised to equal status.

The principal design features for medical nonwoven fabrics are barrier properties, strength, sterilization stability, breathability and comfort for garment applications.

Barrier performance

Barrier requirement can be partial ("-resistant") or total ("-proof"), ranging from particulates and bacteria to fluids and viruses. e.g. "Higher Efficiency Allergenic Bedding", basically an SMS which meets the dust and particle barrier performance[23,38] . In general, a hydrohead of > 40 cm is required to compete in this market. To date, the only products that consistently pass the viral barrier test are fabrics reinforced with impervious film.

The strength requirement vary with the end use application. For surgical drapes, stiffness is very critical because barrier performance may be affected by conformability to patient or equipment. Good abrasion resistance is a necessity for the safety of barrier materials. Flame resistance is needed especially for laser applications and oxygen administration. The Consumer Product Safety Commision (CPSC) require 3.5 second burn time on CS-191-53 for gowns, head coverings, and surgical masks[30].

Sterilization stability

Many hospitals have added peroxide plasma systems, such as STERRAD, to their standard steam autoclaves and ethylene oxide chambers in the Central Supply Room. When designing fabrics for sterilization it is essential to understand the impact of sterilization procedures on fabric performance features. Steam autoclave generally operate at 121-132°C. In Europe, flash sterilization temperatures upto 138°C have been proposed in response to concerns about Jakob-Crueztfeld Disease, the "mad-cow" disease. Polymer selections must be made accordingly. Fabrics containing cellulosics are not recommended for the plasma units as these fabrics retain residual peroxide.

Comfort and breathability

The comfort and breathability factor is usually considered as opposing the barrier function. For sterilization wrap, the issue is that the barrier must prevent dust and micro-organisms from penetrating a sterilized package during storage and transportation. At the same time it must be porous enough for the sterilant to penetrate the wrapped package and completely sterilize the contents of the surgical set.

Another facet of comfort is often described as "drapeability" and hand. Fabric flexibility also affects comfort and permits easy moulding over the body in surgical drapes[19]. For gowns, comfort and stiffness may affect perspiration and movement.

Linting

For gowns, linting is not wanted because particles from gown or drape may complicate the wound healing process. Products that release particles visible to the eye into air during package opening or product use cause significant concern in the field. In general, it is accepted that particle above 50μm are readily visible to the unaided eye[18].

ABSORBENT HYGIENE PRODUCTS

The first industrially manufactured disposable hygiene products were probably the sanitary napkins placed by Johnson & Johnson on the US market in 1896. They consisted of a cotton wool pad wrapped in muslin gauze.

Functions/Properties

Baby Care

Baby Diapers: absorb urine during miction; retain urine inside the absorbent core; isolation wetness from the baby's skin; containing faeces from the baby's skin; isolating urine and faeces from the baby's environment (clothes, bed, etc)
Pant Diapers: the important difference between Pant Diapers and Training Pants is that the absorption capacity of the pant diaper is equivalent or better than a corresponding child size diaper.

External Feminine Hygiene

Sanitary Napkins: absorb and retain menstrual fluid; isolate menstrual fluids from the body. Important / Desired Properties : no leakage; no unaesthetic appearance or colour; no odour; no noise; stay in place; comfortable to wear (thin body shape).
Panty Shields : protects the wearer's panty from body exudates.
Important / Desired Properties : sufficient absorption capacity; discretion; comfortable to wear (softness, body shape).

Internal Feminine Hygiene

Tampons: absorb and retain menstrual fluid inside the body.
Important / Desired Properties : no leakage; no odour; easy to insert / remove; softness; comfortable to wear (dimensionally correct).

Adult Incontinence

Heavy Incontinence: absorb urine during miction; and subsequently distribute the urine throughout the absorption pad; retain urine and faeces inside the product; isolate wetness from the skin; reduce odour.

MATERIAL USED IN NONWOVEN PRODUCTS AVAILABLE IN THE MARKET

For the production of nonwovens for the medical and sanitary domain and for products in the personal and healthcare mainly three fibres types are used : cotton, rayon and wood pulp and cotton linters[13,14,15,16,31].Until now, nonwovens have only been made from staple fibres, Sandler has now produced nonwovens directly from granulated polymer for hygiene under trade name of "sawascreen", which are also antimicrobial finished[6,9].
Cotton-surfaced nonwovens (CSNs) have been developed with cotton on one or both sides of a base structure, generally a spunbonded polypropylene web, in which the cotton content varies from 30-70% of the fabric weight. CSNs are made during spunbond polypropylene production by placing the carded cotton / polypropylene web one or both sides of spunbonded polypropylene filaments web prior to the spunbond calender.
Cotton-core nonwovens (CCNs) are thermally bonded laminates with cotton cores and outer layers of melt blown and / or spun bonded webs which are engineered to effectively transport liquid into the highly absorbent cotton core from the surface. The dry surface and absorbent core makes CCNs highly suitable for products such as diaper components, feminine hygiene pads, wipes for baby, surgical packs (barrier gowns, drape)[20].

Table 3

Fabric End Use	Production Methods
Cover stock	Card, Air lay, Wet lay, Spun-bond
Surgical Fabric	Composite, Spun-bond, Melt-blown, Spun laced
Wipes / Towels	All types
Bedding	All except wet lay

Non woven disposable surgical caps are made of cellulosic fibres with the parallel-laid or spun laid process. Hydroentanglement is gaining popularity for surgical drapes and gowns. Table 3 shows end uses and production methods of selected nonwovens[29].

Baby diapers, training pants and pant diapers

These products utilise cellulose fluff combined with superabsorbent polymers, SAP, (normally in powder form) to create the absorbent core which acts as the storage structure in the product. In some products, wetlaid cellulose tissue may be used as a containment wrap around the cellulose pulp / SAP core structure[25,34].

The coverstock or topsheet layer is a nonwoven material which may be spunlaid polypropylene web or a staple fibre thermally bonded nonwoven, and the web normally treated to confer either hydrophobicity or hydrophilicity, depending on the application.

Modern products, particularly top range products, incorporate an acquisition / transport layer which may be formed of synthetic staple fibres thermally bonded in nonwoven structure, or may be a structure formed from chemically and / or mechanically modified cellulose fibres. For the products to fulfill primary user requirements, the absorbent material, when wet must be contained and isolated from the babies clothes or bedding. This function is carried out by the back sheet, which may be a polyethylene film structure or a film / nonwoven composite. i.e so-called "textile backsheet" (TBS), which may also be breathable.

Sanitary napkins and panty shields

These products may utilise cellulose fluff pulp / SAP combinations to create the absorbent core or it may entirely consist of pulp. Conversely the absorbent core may comprise a short fibred nonwoven web made from thermally stabilised cellulose fibres or be based on melt blown polypropylene.The top sheet can be staple fibre polyester nonwoven, a polypropylene nonwoven or a perforated film.

Tampons

The absorbent core structure of the tampon is made of cotton, viscose rayon or blends of these two types of fibres. A light carded bicomponent nonwoven may be used as a soft coverstock.

Adult Incontinence Products

The absorbent core of these products is normally from cellulose fluff pulp. The top sheet material is usually a spunlaid polypropylene nonwoven web and the backsheet a polyethylene film[4,24,34].

CONCLUSION

For nonwovens, there are excellent future prospects which can be further extended by product and processing innovations. The spunlace technology in combination with the air laid technology provides high performance lines for cost effective and non polluting production of nonwovens for the medical industry. Usage of nonwoven materials is advantageous in healthcare and hygiene sector due to shorter production cycles, lighter weight, flexibility and versatility in incorporating various mechanical properties, their disposibility, which reduces cross infection and enables high levels of hygiene to be maintained in medical application and lower production costs. Demand for Baby Daipers, Feminine Hygiene products and other disposable nonwoven products is growing day-by-day and is supposed to continue in coming years too.

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ROLE OF ADVANCED TEXTILE MATERIALS IN HEALTHCARE

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ABSTRACT

The growing awareness of, and demand for, better healthcare, particularly in developed nations, is a major factor in moving the medical textile market towards high value added niche product segments. Disposable medical products are experiencing phenomenal growth due to the growing awareness of infectious diseases, critical reassessment of clinical practices for improved clinical hygiene and need for advanced materials for better healthcare at lower cost. This requires the simultaneous applications of wide ranging technologies to develop new advanced textile materials to address the diverse needs of the healthcare industry.

The traditional applications of textiles in healthcare, including non–implantable materials, such as wipes and swabs, gauzes, bandages, wound dressing, surgical wear, masks, orthopaedic applications, light support and compression garments, are also receiving constant attention for more innovative developments to provide better care and cure. However, recent radical developments in the field of surgical implants, extra-corporeal devices, tissue engineering, antimicrobial barrier fabrics, hard-tissue applications in orthopaedic implants, cardiovascular devices, endovascular treatments, biosorbable polymeric and even "wearable vitaminized" fibre materials have resulted in radical changes in the medical textile industry. To develop these new applications, polymer scientists, physicist, doctors and textile researchers have joined hands in conducting the required advanced multi-disciplinary experiments. This paper will discuss both traditional and new developments in medical textiles, with the emphasis on recent high-tech applications. This paper will also deal with emerging textile products, such as sensor embedded fabrics for diagnostic and monitoring applications of patients in healthcare. Such "sensitive" fabrics and garments containing sensors and conductive fibres, and termed "wearable electronics" or "intelligent textiles", can be interfaced with microprocessors for monitoring heart beat, body temperature, stroke patients in bed, tightness of pressure garments, CAT scanning and medical imaging.

INTRODUCTION

Healthcare is a serious business which is not only influenced by practising medical professionals but also by the manufacturers of diverse medical products. In today's healthcare environment, textile products are finding innovative applications which were not imaginable just a few years ago [1]. The importance of textile materials in medical fields is credited to their excellent physical properties, such as strength, extensibility, flexibility, suppleness, air and moisture permeability and wicking. The various applications of textile materials in medical and healthcare industries may be broadly categorised as follows [2]:

1. Hygiene: These are primary healthcare products meant for protection, general hygiene and healthcare, including bedding clothing, mattress covers, surgical gowns, face masks, head and shoe covers, apparel, sterilisation wraps, incontinence care pads, nappies, tampons etc.

2. Extracorporeal: These arc extracorporeally mounted devices used to support the function of vital organs, such as kidney, liver, lung, heart-pacer etc.
3. Therapeutic: The products used for treatment and cure of diseases due to ill health, such as heating pads.
4. Nonimplantable: These are materials used for wipes, swabs, wound dressing, bandages, gauzes, plasters, pressure garments, orthopaedic belts, etc.
5. Implantable: These are materials implanted on or in the human body to either support or replace the functions of internal organs. Besides classical implanatble textile materials, such as sutures, recent advancements in medical treatments have found new applications, such as heart valves, vascular grafts, artificial veins, artificial tendons and ligaments, artificial joints and bones, artificial skin, artificial cartilage etc.

While many textile materials used in traditional applications in healthcare are still found, recent developments in the advanced healthcare have led to the development of new materials through cross-cutting research approaches in the fields of textiles, polymer, biomedical, pharmaceutical and medical sciences. This paper deals with such modern developments in various healthcare applications discussed above.

FIBRES FOR MEDICAL AND HEALTHCARE APPLICATIONS

Fibres from natural origins such as cotton, silk and regenerated cellulose; and fibres from synthetic origin, such as polyester, nylon, polytetrafluoroethylene, polypropylene, carbon and glass are widely used in medical and healthcare applications. The above mentioned natural fibres are mainly used in nonimplantable materials and most of the synthetic fibres are used for implantable as well as other high-performance products. Figure 1 shows the classification of fibres used in medical and healthcare applications.

Besides these multi-purpose commodity fibres, speciality fibres from a variety of polymeric fibrous materials have been derived from natural polymers, such as alginate, collagen, chitin, chitosan, polylactic acid etc. and are now-a-days finding innovative medical applications due to their biodegradability. Such materials are absorbed in the human body within a short period. Collagen fibres are used as sutures for surgery inside the human body and modified collagen fibres for applications in contact lenses. Calcium alginate fibres are used for wound dressing due to their non-toxicity and haemostatic properties as well as their bio-degradability [3]. Chitin/Chitosan fibres are derived from natural biopolymers possessing excellent medical properties such as antibacterial, chelating, immunostimulation and wound-healing [3,4]. Nonwoven fabric made from chitin fibre can be used as artificial skin, adhering to the human body for quick healing. Membranes from chitosan can be also used for drug delivery systems. Collagen is a protein fibre from biological origin, obtained from bovine skin and is commonly used for fibrous dressing products, sutures, surgical implants etc. Catgut is another fibre from biological origin derived from the small intestines of sheep, oxen, horse and ass.

Fibres manufactured from polyvinyl alcohol (PVA) resin are soluble in an aqueous medium at temperatures above 93° C. The fabrics produced from PVA fibres are very useful in certain medical applications, such as towels, sponges and gauzes, which after use can be disposed of using a hot water bath. This provides great relief to hospitals particularly while handling infectious medical waste of disposable products without going through expensive landfill or incineration methods requiring additional handling which increases the risk of exposing health-care workers to infectious diseases, such as hepatitis-B and acquired immune deficiency syndrome [5].

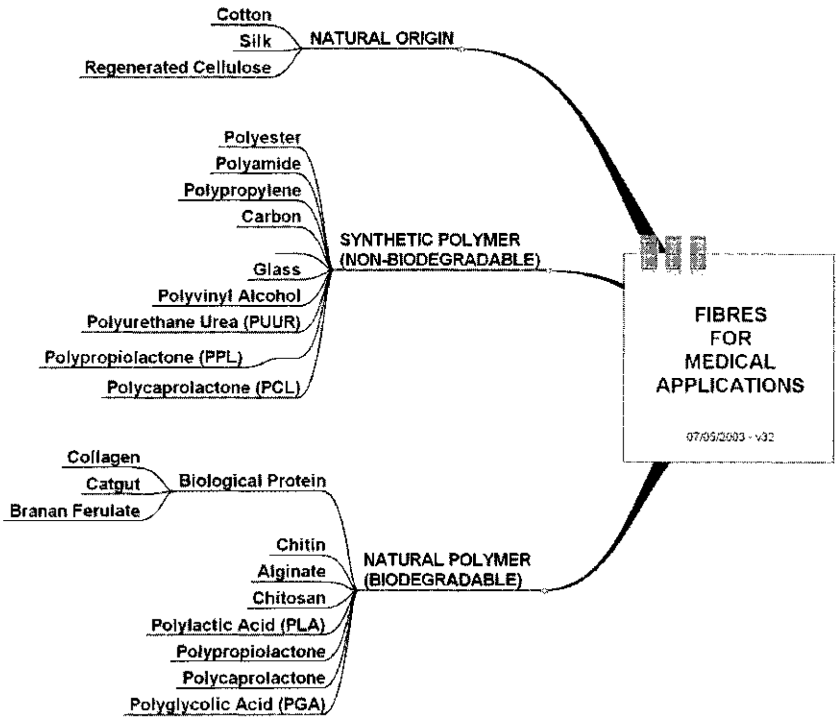

Figure 1: Classification of Fibres for Medical Applications (Ref. 3,4,17)

In recent years, attention has been given to naturally-derived, bio-degradable polymer materials, not only because they have advantages for the point of view of waste disposal and environmental friendliness, but also because of their use in the medical field due to the biocompatibility, biosafety and bioabsorbale properties of some of them. Such materials being biodegradable and bioabsorbable, exploitation as a material or in technologies in drug delivery systems has been explored. Poly Lactic Acid or Lactide, generically known as PLA fibre, is one such material which is derived from natural raw materials (starch and cellulose) and is completely biodegradable. Researchers in Japan have used Poly L-lactic acid (PLLA) fibres for developing drug delivery system for surgical implants [6]. The research directed towards finding new bio-compatible polymers which can be extruded into fibres is still continuing. Due to limitations in obtaining medical grade fibres of the desired purity research is continuing in finding different biopolymers which can be utilized in medical applications. Medical textile research groups at the Institute of Textile Technology, RWTH Aachen recently spun polyvinylidene fluoride (PVDF) and poly D-lactid (PDLA) multifilaments which can be converted into staple fibres to make needle-punched nonwovens for scaffolds for tissue regeneration of periodontal defects [7].

Bioactive fibres are new modified man-made fibres manufactured to resist and control the growth of potentially harmful micro-organisms. They are produced by introducing the antibacterial additive during the spinning stage depending upon the intended use in hospitals, medical or home textiles. Such textile materials from bioactive fibres offer protection against cross transmission of diseases, and hygienic anti-microbial dressing provides an antiseptic covering to wounds and incisions to prevent contamination and infections [8,9].

ADVANCED MEDICAL TEXTILES

New hygiene/medical products:

New medical treatments are increasingly demanding textiles with improved bioclimatic and hygienic properties, such as [10]:

1. Protection to skin from liquids, particles and bacteria
2. Effective barrier against germs, fungi and attendant risk of infection
3. Thermoregulatory characteristics
4. Moisture absorption and liquid absorption.
5. Ease of laundering, sterilisation and antistatic behaviour.
6. Low level of textile chemicals and dyes with high mechanical stability.

Functional spacer fabrics, essentially a three dimensional structure, can provide the above attributes and they are often superior to conventional textile materials for medical applications, such as bedding for preventing bedsores, orthopaedics casts, bandages etc.

Hygiene fabrics from new speciality fibres include biodegradable nonwovens from a mixture of polycaprolactone, polypropiolactone and regenerated cellulose fibres. New fabrics are being developed to resist bacteria, mildew, fungi, stain and odour for healthcare applications. Anti-allergen finishing agents are used for fabrics to provide relief to patients suffering from asthma and prone to allergies caused by dust mites. Textiles with aromatherapeutic effects represent new materials which are produced by micro-encapsulation carried out by means of interfacial polymerisation on the surface of finely dispersed droplets of aromatic oil or perfumes in aqueous medium. The microcapsules break and release the perfume during use. Such materials can be also used for bed and pillow covers of patients to control healthcare related foul odours.

Various types of antimicrobial fabrics from different fibres are under development. The fabric is impregnated in antibacterial agents to increase the efficacy of the finished fabric to arrest the bacterial growth. Such material can be used for the uniforms and dresses of healthcare workers so as to prevent transmission of bacteria to patients. To impart permanent antibacterial properties, antibacterial agents have been incorporated in the polymer during spinning. Anti-viral fabrics have been developed in Japan recently for resisting viruses and microbes, thereby protecting patients against infections, this is particularly important for patients with impaired immunity and who are susceptible to serious infection. The applications of such anti-viral fabrics include filters for hospital air cleaners, face masks, immobilising beds for biologically active substances and carriers for sustained drug release. Barrier fabrics to protect both patients and medical staff against blood-born cross-infection of hepatitis B and HIV are also being developed.

Woundcare and bandages

Modern woundcare is moving from the traditional concept of clinical cotton, gauze, tapes and cotton bandages, to more sophisticated wound dressing and management techniques to alleviate the need for frequent replacement and attention of the healthcare professionals. Although dressings for the different types of wounds are normally different, the modern dressings, besides being non-toxic, are designed to provide a barrier against micro-organisms, dirt, liquid and other foreign bodies, breathability, cushioning effect, absorbency to control exudates and ease of removability without causing pain and trauma to patients [4,11].

Modern textile materials used for wound dressings fall into three main groups, namely, absorbent, semi-permeable membranes and non-adherent materials [11]. In traditional wet-to-dry healing techniques, the gauze and fibres from cotton dressing tend to adhere to exudates, causing trauma when removed due to the drying-out of the wound after a certain time. New wound management techniques, therefore, concentrate on moist wound healing, where the body's own exudates are allowed to remain in contact with the wound, as opposed to removed by wicking as used in traditional dressing [12]. Dressings made from calcium alginate fibre nonwoven fabric help to keep the wound moist, the material itself also being absorbed into the body [13]. Chemically converted Lyocell based fibre dressing is used for the treatment of chronic wounds, pressure sores, leg ulcers and burns as an alternative to calcium alginate [14]. Biologically active textiles produced by chemical modification of fibre forming polymers -mainly cellulose- with medicinal preparations have been developed recently to treat pyro-necrotic wounds, burns, and frostbite [15]. Fibrin bandages are developed by saturating a biodegradable cloth with blood clotting chemicals and an enzyme purified from human blood. This wound management technique prevents excessive blood loss in severe injuries, such as gun shots and automobile accidents [16]. Other wound care dressings are based on chitin and chitosan which are absorbed by the body. A wound facing layer, consisting of chitin, and backed by an expanding polytetrafluoroethylene – fibre nonownen fabric which acts as a barrier to bacteria and water has been developed for healing wounds. The nonwoven fabric made from chitin fibres can be used as an artificial skin for treating burn wounds [3]. Collagen fabric is also employed as a wound covering material for certain wound dressings.

Bandages are probably the most important medical textiles and are used for different purposes, namely, for retention of dressing, for providing support to joints and prevent the development of oedema, for exerting pressure on a limb, for treating skin diseases and for providing protection against physical damage. The fibres and fabrics used for bandage applications are dependent upon their intended functions. Warp knitted spacer fabrics, elasticated woven fabrics, tubular knitted hose with Lycra, nonwovens etc. are very widely used for bandage applications.

Sutures

Silk is a traditional fibre used as sutures in medical application. Though biodegradable, the major drawback of silk is its lower tensile strength and reaction with tissues. Polyester, nylon and polypropylene filaments offer excellent strength and they can be used as non-absorbable sutures due to their non-biodegradability. Bio-absorbable and biodegradable natural materials, such as collagen and catgut fibre, can be used for implantable sutures in internal surgery, however, the commercial availability of the medical grade material is scarce and they suffer strength loss during use due to their reaction with body tissues.

Newer suture materials from synthetic aliphatic polyester fibre, made from glycolide homopolymer, are biodegradable and strong enough to find applications in vascular and micro surgery of internal organs. The problem of strength retention in the case of bio-absorbable commercial sutures is being tackled by different surface modification techniques. Polypropylene and polyester filament coated with Teflon® are also employed for vascular surgery. Carbon fibre based sutures are also produced by the modification of cellulose filament.

Medical implants

Increased usage of fabric and fibre products in medical implants is attributed to tough regulations for product liability to protect patients and clinical personnel. The increased awareness of this need for protection, is driving new research in biomaterials demanding multi-disciplinary expertise, the use of textiles in the construction of surgical implants having greatly expanded. The use of textile materials for different applications of surgical implants is shown in Figure 2.

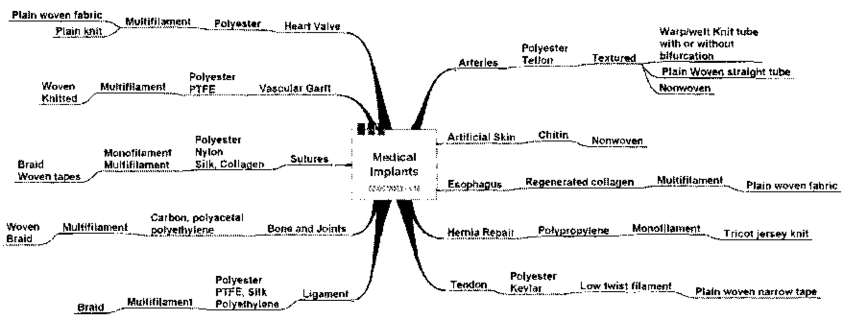

Figure 2: Classification of Medical Implants

Currently, tissues for reconstructive surgery are used from the patient's own cells taken from other parts of the body. Sometimes such reconstructive surgery leads to complications due to infections and the inadequate functioning of the patient's immune system. Therefore, tissue re-engineering, using synthetic materials, may prove a better alternative [17]. Materials used in medical implants include biodegradable and non-biodegradable polymers, such as polylactide and polyester, respectively. New biodegradable polymers are also currently under development to replace some of the non-biodegradable polymers presently used in medical implants. Most implants are made from synthetic polymers, metals or ceramics. Such implants may fail due to long-term complications arising from infections, immune reactions, mechanical failure and lack of biocompatibility with surrounding tissues [18].

Three dimensional textile scaffolds, from biodegradable materials with specific properties are required in addition to the new cell adhesion-specific materials for tissue regeneration. Such a composite material helps in reconstruction of functional tissues using only host cells without the need for residual artificial materials [18]. Small diameter warp-knitted tubular structures made from biodegradable fibres enmeshed with fibroblast cell culture have been developed [18]. Traditional metallic implants used in orthopaedic surgery for healing bone fractures have inherent drawbacks in terms of stiffness and the need for further surgery to remove them when the fracture has healed. Biodegradable polymers, such as polylactic acid and polyglycolic acid, have recently been used for holding the bones together while new bone tissue grows into the gap. Unfortunately, these polymers are weak and have poor bending stiffness and shear strength so they are applied only in the case of bone fracture healing where they do not have to bear large loads. Research is in progress to modify these polymers to improve their load bearing capacity [19]. Fibre-reinforced composite materials are also under test for bone replacement.

Artificial mess grafts/skin from absorbable polymers, in combination with human skin cells, are now being used for treating burn wound. Biodegradable polymers, such as polyether/polyester copolymer and also poly-L-lactide, have been used for skin regeneration, to replace conventional 'human cadavar allograft' with a nylon fibre-mesh fabric for the treatment of severe burn wounds [20].

Intelligent textiles

Intelligent or 'smart' textiles is an emerging field in textile research, where the material is designed to sense and react to different stimuli or environmental conditions [21]. An important development applicable to the medical field is the 'wearable computer system' [22,23]. For example, a smart T-shirt with conductive fibres capable of feeding sensor signals into a small transmitter has been manufactured. Such apparel capable of recording, analysing, storing, sending and displaying biofunctional data including internet connectivity can be used to monitor the health status of the wearer. It was originally designed for combat soldiers in the military to detect the location and severity of wounds and subsequently to monitor their physiological state, and to transmit the information to remote medical sites. The concept was later extended to medical applications in which the transmission of data from such a 'wearable computer' enables the remote monitoring of heartbeat, blood oxygen level, respiration and body temperature to start with. The health status can also be interpreted and transmitted to a doctor's office or to a hospital monitoring system as required. Such a 'smart' system can also be used for monitoring babies considered at risk for sudden infant death syndrome, keeping watch on post-surgical geriatric patients at home, remote monitoring of stroke patients in bed, tightness of pressure garments, heat stress suffered by fire fighters and three-dimensional scanning and medical imaging of patients. Research and development on such clothing containing biosensor technologies is still continuing and software algorithms to monitor more than 30 physiological signs have already been developed. Smart bandages are also under development. These are wearable pads embedded with sensors to collect clinical data. Smart eye patches for treating a child suffering from amblyopia in which one eye is significantly weaker than the other, have also been developed recently. The smart eye patch is made from an absorbent pad with an adhesive strip which contains contact-sensitive sensor, a timer and a battery and an external port to transmit data between the eye patch and a host computer. This allows the ophthalmologist to ensure that the patch is correctly positioned on the child's eye and instructions are followed for effective care [24].

The concept of smart textiles is also being extended to new finishes, for example, to provide vitamins to the body through garments, termed as 'wearable vitamins'[25]. Fuji Spinning has developed a finish to fix pro-vitamins to fibres in a stable manner. A finished Tshirt, containing vitamin C and also E now, has been developed. The wearer's skin can absorb these vitamins to receive the daily requirement of vitamins C and E.

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IMPROVING THE QUALITY OF LIFE AND COMFORT IN WOOL AND BLENDED FABRICS FOR THE ELDERLY

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ABSTRACT

The garments or products are in the first line of unlimited demand of design towards humanising objects and environment around us – conception centred in the user – either by the needs of wear, and by the proximity that garments have with the human body. From the beginning, the properties that influence comfort that garments transmit to the user are in the top of textile research and development concerns. The comfort added value respecting to garments is a differentiating element that increases, by means of innovation, the competitiveness of companies.

When optimising garments comfort, the fabric technology is of fundamental importance, this being the reason why in this study a greater relevance to the technological component of wool and blended fabrics design is given. The studied properties are the air permeability, thermal behaviour, water vapour permeability and fabric drape. Concerning these properties, the fabric performance must point out to ideal situations near the body microclimate, the air circulation, the natural moisture transfer and the absence of sensorial perturbations.

The elderly refers to people where the higher functionality demands are found, concerning the objects with which people must live everyday. In this context, garments play a very important role to guarantee comfort, contributing to the quality of life of these persons and, through the well being sensation, in a broad sense, to their health.

This study comprises correlation between these four properties and the fabric's structural characteristics in order to search the structural characteristics which are crucial for reaching favourable correlations, so that, by adequately changing them, the optimisation of fabric properties towards comfort can be achieved.

AIR PERMEABILITY

The air permeability measures the ability of fabrics to exhibit their resistance to the penetration of an airflow. In daily life, this airflow may be the wind. Thus, it is defined as the air volume that goes through a given fabric surface during a unit time period, maintaining a given pressure difference between the two fabric surfaces. Kawabata confirms that there is a direct relationship between the airflow and the loss of mass of the majority of fabrics.

THERMAL BEHAVIOUR

When considering the fabric thermal behaviour, the thermal properties of component fibres (such as, it specific heat) develop a secondary role relatively to the air entrapped inside the fabric structure, even knowing that this amount of air clearly depends on fibre characteristics and on the yarn and fabric structures. Among the characteristic parameters, the thermal resistance can be used, this being the ratio between the temperature difference existing at the two fabric surfaces and the amount of thermal energy transferred in a unit of time through a given surface. This quantity indicates the insulating capacity of a fabric. A heat insulating fabric is the one that has a high thermal resistance and vice-versa. It is the fabric thickness that influences the property due to the amount of air trapped inside it.

The thermal resistivity is the ratio between thermal resistance and fabric thickness, this being considered as an intrinsic fabric property, no matter its dimensions. The inverse of thermal resistivity is the thermal conductivity. Textile fibres possess much higher thermal conductivities than air.

Another interesting aspect is the "cold" or "warm" sensation that one feels when a fabric is touched, which is very much related to the subjective evaluation of fabric handle. Stuart and Holcombe revealed that the heat flow that goes through a layer of fibres takes place through the air, fibres and also by infrared radiation.

WATER VAPOUR PERMEABILTY

To assure the comfort moisture level and taking into account that the human body is a natural source of heat and moisture, fabrics must be permeable to water vapour to establish equilibrium. According to Baush and Hosche, the perspiration ability of fabrics is a function of fibre packing density, thickness and weight per unit area that, in a certain way, depends on the type of fibre. Generally, wool fabrics have more perspiration ability than other fabrics. The presence of synthetic fibres in wool blends diminishes this ability. The resistance to water vapour increases with the felting intensity in the milling operation.

FABRIC DRAPE

The fabric drape is a property that is difficult to define and quantify. A way to approach this may be according two ways: aesthetical and comfort. From the aesthetical point of view, fabric drape means shape and volume, more or less pleasant when seeing a garment. From the viewpoint of comfort, the fabric drape means the higher or lower ability of a garment to fit to the body movements. Thus, fabric drape is closely related to bending rigidity. In this study we evaluate fabric drape in its mechanical component, which is the one that influences sensorial comfort. This is one of the parameters that is considered to be strongly related to the subjective evaluation of fabric handle and has to do with their rigidities (bending and shear) and, in the case of garment making, to fit to three-dimensional shapes.

MATERIALS AND METHODS

Selected fabrics

The study was carried out on 31 wool and blended woollen fabrics having different structural characteristics. The only one property which was common to all fabrics, was the existence of wool in their compositions. Thus, selected fabrics different compositions, mass per square metre, yarn types, opacity, weave and finish, so that they were representative of commercial fabrics of the wool industry.

Fabric characterisation

The evaluation of fabric structural characteristics was carried out by laboratory testing and according to current standards, the following presented the tested characteristics and their corresponding units.

- Composition (La, PE, PA, EA) – in % - standard NP 2248
- Average fibre fineness (Fi) – in μ – standard NP 3160
- Average fibre length (Co) – in mm – standard BS 6176:1981(1991) – WIRA apparatus
- Yarn count and number of yarn plies (Tex, NC) – in tex – standard NP 4105
- Twist of yarns and plies – turns/m – standard NP 4104
- Mass per square metre (PM2) – in g/m^2 – standard NP 1701
- Thickness (ESh) – in mm – Standard UNE 40-224-73 – Louis Schopper apparatus
- Yarn density – in yarns/cm – standard NP EN 1049-2
- Weave – standard NP 4114/1700.

Based on the tested structural characteristics and mathematically relating some of them, we find parameters that contribute to the complete definition of fabric construction: Twist Factor (CTt), Weave Coefficient (CL), Weave Type (TL), Average Float (Amed), Cover Factor (FaC), Opacity (CoT) and Porosity (Po). The kind of finish (TA) was also determined according to a 1 to 5 scale as a function of the degree of fabric felting.

Applied measurement techniques

Air permeability

To evaluate the air permeability (PAr) a permeabilimeter FX 3300 from Textest was used, following the NF G07-111 test method. With this test, the resistance of a fabric to the air that goes through it is determined, by measuring the airflow that goes through a fabric surface when this is subjected to a constant suction pressure that pulls the air from outside to inside the apparatus during a given time. The average airflow for the tested specimens, expressed in $ml/cm^2 \cdot s$, was determined.

Thermal behaviour

The evaluation of thermal behaviour of fabrics (ITA) was carried out by means of the Zweigle T675 – Alambeta apparatus, using one of its measuring parameters, the thermal resistance r. This resistance is defined as the temperature difference between the upper (face) and lower (reverse) sides of a fabric having a $1 m^2$ surface area and a given thickness, when the heat flow that goes through it is of 1 watt, that quantity being then expressed in $°K \cdot m^2 /W$. Two sensing plates constitute the Alambeta apparatus. The lower one stays at room temperature and, the upper one, has a constant adjustable temperature.

Water vapour permeability

The water vapour permeability (PVC) was determined following IULTCS (International Union of Leather Technologists and Chemists Societies) standards according to IUP/15 test method developed for leathers. This method comprises the use of an apparatus having the following parts:

- Four flasks with silica inside closed with a lid and with a round opening of 30 mm diameter to hold the fabric sample;
- A disk shape device to hold the flasks rotating at 75±5 rpm by an electrical motor. Flasks are placed in horizontal position;

-A fan placed in front of flask openings generating an air current in the sample direction.

The first test hour is to create inside flasks an atmosphere similar to the outside one, while the two following hours are to measure the increase of weight by the silica, due to the entrance of water vapour inside flasks and through the fabric. This entry is made easy by the air current created with the fan. The water vapour permeability value (PVC) for the fabric under study, expressed in $mg/cm^2 \cdot h$, results from the average of four samples and is determined using the equation $PVC=(7639 \cdot m)/(d^2 \cdot t)$, where t is the time in minutes between the two consecutive weightings, m is the increase of weight in mg and d is the flask opening diameter in mm (30 mm in this case).

Fabric drape

The test method used was based on BS 5058:1973 standard. Test specimens of 30 cm diameter were used, tested from both sides in the Cusick Drape Tester. The light projected originates the fabric shade on a paper. Following, the contour of the shade is drawn on the paper. The paper is than cut by the line drawn. Two weightings are made, one with two pieces of paper together (M_1) and other only with the paper corresponding to the shaded area (M_2). To evaluate the fabric drape (Ca), in percent, the following equation was used: $Ca=(M_2/M_1) \cdot 100$.

RESULTS AND DISCUSSION

Equations that best explain the properties

The best-fit equations determined to explain the comfort properties and respective correlation coefficients (R^2) and significance levels (P) are shown in table 1.

Table-1 Relationships for Comfort Properties

Fabric family	Equation	R^2 (%)	P (%)	Accuracy level
	Comfort property – Air Permeability			
Woollen	**PAr** = -120,75+1,96**Po**-0,38**CoT**+ 3,19**Fi** +0,36**CTt×NC**+0,12**Tex**-0,21**PM2**	96,4	0,1	High
	Comfort Property – Thermal Behaviour			
Woollen	**ITA** = 0,0667+0,0600**ESh**-0,0008**Po** +0,0007**Amed**-0,0001**PM2**	98,1	0,1	High
	Comfort Property – Water Vapour Permeability			
Woollen	**PVC** = 40,54-0,97**CoTm**-0,04**Com²** +0,22**CTtm²**	61,6	0,1	Medium
	Comfort Property – Fabric Drape			
Woollen	**Ca** = 0,93+1,77**TA**+1,35**Fi**+0,07**PM2**	86,9	0,1	Medium

Importance of equation variables

The relative weight of equation variables, which most explain comfort properties, is shown in table 2.:

Table-2 Relative Weight of the Important Variables

Comfort Property	Fabric Family	Variables (%)			Not Explained
Air Permeability	Woollen	Fi – 64	Po – 13	PM2 – 12	4 %
Thermal Behaviour	Woollen	ESh – 94			2 %
Water Vapour Permeability	Woollen	CTt – 41	CoT – 16	Co – 5	38 %
Fabric Drape	Woollen	PM2 – 50	Fi – 26	TA – 11	13 %

Discussion of equations

Discussion of air permeability equation

The analysis of the equation that explains the property under study leads to the conclusion that air permeability (PAr) increases with the increase of average fibre fineness (Fi) and porosity (Po) and with the decrease of weight/m^2.

In our study, the increase of average fibre fineness means the increase of fibre diameter with the consequent increase of crimp. The fibre fineness influences yarn and fabric structures. Thus, due to spinning capacity and cost reasons, coarser fibres are used to make higher count (tex) yarns. Because of coarser yarns and higher crimp, fabrics show higher porosity, this means, the spatial fibre arrangement in the yarn is not so compact as in the case of thinner fibres, since a smaller diameter allows an higher number of fibre contact points.

On the other hand, a change of yarn count implies a change of yarn density, assuming cover factor and weight/m^2 constant.

With the increase of fibre fineness, conditions are set to improve air permeability, either increasing porosity, or increasing yarn count (tex).

Discussion of thermal behaviour equation

The contribution of fabric thickness to the explanation of its thermal resistance is because that characteristic influences fabric porosity. This gives the percentage of fabric volume that is occupied by air instead of textile material. In woollen fabrics, porosity ranges from 67 to 86%, while in the worsted ones it lays between 59 and 73%, their average values being 76 and 64%, respectively.

The volume of a square meter of fabric is a function of its thickness. In general, thicker fabrics give higher weight/m^2, although not in a proportional way. Thickness increases more rapidly then weight/m^2, since there are other influencing parameters such as fibre type, weave and kind of finish. Thus, the increase of this characteristic and the corresponding increase of fabric volume are generally related to a higher amount of air inside fabric. Thus, the increase of porosity and thickness for the same weight/m^2 has a positive contribution of fibre crimp, weave floats and felting and/or raising finishes.

It is known that air thermal resistance is six times higher than that of majority of textile fibres. For this reason, we can conclude that it is the entrapped air inside fabric that mostly influences its thermal resistance, and increases with the increase of fabric thickness.

Discussion of water vapour permeability equation

The analysis of equation that explains the property under study leads to the conclusion that water vapour permeability (PVC) increases as fabric opacity (CoT) decreases. Water vapour permeability reaches a minimum for values of yarns twist coefficient (CTt) near 37 turns·m^{-1}·$tex^{0.5}$·10^{-2}. The water vapour permeability shows a maximum for values of average fibre length (Co) near 51 mm.

The yarn twist coefficient is the variable that mostly influences water vapour permeability of woollen fabrics. According to the equation, this influence may assume two different situations; one for twist factor values up to 37 turns·m^{-1}·$tex^{0.5}$·10^{-2}, and the other for the values above. However, by observing both regions of the plot, we can conclude that the first situation is only verified due to a one fabric made of two ply warp and weft yarns present in the studied fabrics universe (figure 1.).

When considering the yarn twist coefficient corresponding to the final twist, this is, to the ply twist, we probably are taking into account non-comparable variables. Thus, we consider that water vapour permeability increases with the twist coefficient. On the other hand, an increase of twist coefficient (for the same count) represents a decrease of yarn diameter, fibres becoming more compact and giving rise to bigger spaces between yarns, thus increasing water vapour permeability.

Discussion of fabric drape equation

The analysis of equation that explains the property under study leads to the conclusion that fabric drape (Ca) increases with weight/m^2 (PM2), average fibre fineness (Fi) and finish type (TA).

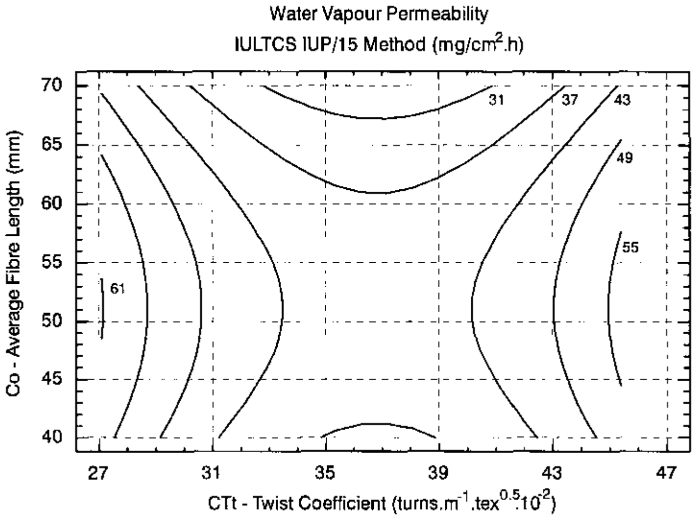

Fig 1. Influence of twist coefficient and average fibre length on water vapour permeability.

For this fabric group, the structural characteristic that mostly influences drape is fibre fineness. As a matter of fact, and according to strength of materials, the thinner the fibres the lower its bending rigidity and, thus, the less rigid is the fabric.

Concerning the influence of finish type on drape of fabrics having felting intensities up to 3, it cannot be confirmed by a linear regression between both parameters. Figure 2. shows that this influence is very small. For higher finish levels (above 3) the influence is quite evident.

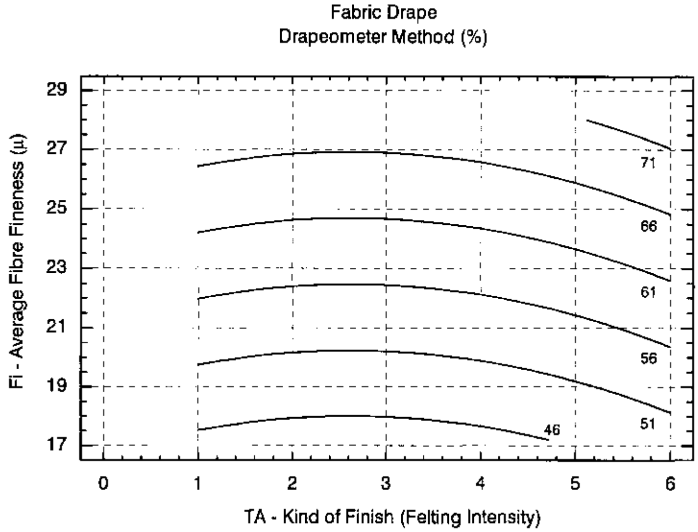

Fig 2. Influence of kind of finish and average fibre fineness on fabric drape.

This means that the existence of surface pile or the low felting effect on fabrics does not influence rigidity. This is influenced by a marked felting degree or by raising. Fabrics with higher finish levels, besides having higher thickness and weigjht/m^2, have also higher internal cohesion due to fibre entanglement. Either one of these situations can cause an increase of fabric rigidity.

Concerning the influence of weight/m^2 on the drape of these high porosity fabrics, an increase of weight/m^2 is generally followed by a thickness increase, the material density not changing significantly, this meaning that it is the fabric thickness that influences drape.

CONCLUSIONS

The elderly require higher performance or properties from everyday clothing etc. In this context, garments play a very important role in guaranteeing ingcomfort, contributing to the quality of life of these persons and, through the well being sensation, in a broad sense, to their health.

The comfort properties, air permeability and thermal insulation present equations having fabric structural characteristics as variables. These equations explain with a high determination coefficient (R^2) the studied phenomena. The equations for comfort properties, water vapour permeability and fabric drape explain satisfactorily the studied phenomena.

Based on these equations and changing the most relevant variables concerning the explanation of the respective comfort properties, these fabric properties can be optimised as a function of use.

Since the variables are not completely independent and influence more than one comfort property, the improvement of one property may cause degradation of another.

The best solution comes out from the establishment of a compromise between fabric structural characteristics and its performance relatively to comfort properties. In order to predict these properties accurately, a computer programme is being developed.

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USING ULTRASONIC ENERGY FOR BLEACHING COTTON IN HYGIENE TEXTILES

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ABSTRACT

Bleaching is an important step of textile processes which improves the absorbance properties of cotton fibres. Conventional method has some difficulties such as higher time and energy, water consumption and damaging the ecology. The use of ultrasonic energy in textiles, might impart a new improvement to a bleaching process.

This paper is about the hydrogen peroxide bleaching of cotton fibres and cotton spun yarns using of ultrasonic energy. The method solves most of the difficulties in bleaching, i.e. reducing time and decreasing energy consumption. In this work, first a variety of Turkish raw cottons were treated with H_2O_2 at different temperatures and times and later, 100% cotton spun yarns (Ne22) produced from these cottons were bleached with hydrogen peroxide again at different temperatures and times in a ultrasonic bath. The results of the bleached cottons and bleached yarns were also analysed spectrophotometrically.

Keywords: cotton fibre, 100% cotton ring spun yarn, hydrogen peroxide bleaching, ultrasonic energy

INTRODUCTION

Wet processing of textile materials uses large quantities of water and energy and also takes a considerable amount of time. Ultrasonic energy has been used for many years for cleaning vessels, dispersing pigments and influencing chemical reactions. Later it has been discovered that ultrasound can be used to enhance reaction rates, reduce scouring and dyeing times and improve whiteness of textile materials. Ultrasonic energy can be used to modify washing, desizing, scouring, bleaching, dyeing and finishing. Using ultrasonic energy in wet processes has potential in reducing amount of process time, energy and chemicals used, as well as improving in product quality. As it is well known, bleaching is the removal or lightening of coloured materials and hence increasing the whiteness index of the textiles. On the other hand, the brighteners make the textile materials surface appear whiter and brighter by selective absorption of the ultraviolet component (300-400 nm) of visible light. Instead of using conventional bleaching (hot and cold processes) techniques using an ultrasonic energy therefore can be adopted succesfully. By doing this, there may also be an oppurtunity to obtain higher whiteness values for the cellulosic materials than the cold conventional bleaching and this may increase the fibre's absorption properties which is especially essential for the hygiene textile materials [2],[3].

Definitions: *whiteness index* is the situation of being %100 whiteness index of textile material which has the ability of reflecting light. CIE whiteness index W (for 2° standart observer) or W_{10} (for 10° standart observer) formulates as shown below [1].

$$W=Y+800(x_n-x)+1700(y_n-y)$$

$$W_{10}=Y_{10}+800(x_{n,10}-x_{10})+1700(y_{n,10}-y_{10})$$

In this formula x, x_{10}, Y, y_{10} are the colorometric values calculated by the using 2° and 10° standard observers' values under D_{65} illuminant. x_n, $x_{n,10}$, and y_n,$y_{n,10}$ are the cromatisite coordinates of D_{65} illuminant belong to 2° and 10° standard observer. Whiteness index of diffusioner has ideal reflecting property is 100.0.

MATERIALS AND METHODS

In this work, two different micronaire of Turkish cottons were used; one cotton is abbreviated **A** and the other is coded as **B**. Later the Ne22 ring-spun yarns of these samples were produced at twist constant of α_e 3.8. The fibre properties of these two cottons were tested on the HVI 900 at 20 ± 2 C^0, 65% ± 2 RH conditions. The details of the raw cotton fibres are given in Table 1.

Table 1. Raw Fibre Parameters

Fibre Properties	Cotton A	Cotton B
Micronaire	3.74	4.61
%50 Span length(mm)	25.6	15.1
%2.5 Span length(mm)	30.0	31.7
Uniformity	85.4	47.6
Strength(g/tex)	32.2	44.6
Elongation(%)	9.6	10.2
Amount	655	695
Rd	76	72.2
B	10.9	10.8
Colur Grade	22-1	32-1
Leaf	2	5
Area	0.97	2.82
Count	65	85
Whiteness Index of Unbleaced Cotton (W)*	34.8	39.2

*measured on the Datacolor Spectraflash 600 PLUS

The cotton samples of different micronaires (3.74 mic, 4.61 mic) and the produced yarns of these cottons were then bleached with hydrogen peroxide (5 ml/L) at two different temperatures (20°C, 40 °C) and for two different times (30 min, 60 min). The H_2O_2 bleaching receipe was carried out on the BRANSON 2200 ultrasonic bath as below:

Liquor Ratio: 1:30
H_2O_2: 5 ml/L (33.5 %)
Wetting agent: 1g/L
Stabilizer: 1g/L (Prestogen)
NaOH: 1g/L

Later, the bleached cotton samples were measured spectrophotometrically on the Datacolor Spectraflash 600 PLUS for their whiteness index (W).

RESULTS

The cotton fibres and cotton ring-spun yarns were bleached with hydrogen peroxide using of ultrasonic energy. The overall results of these samples are given in Table 2 and their graphics are presented in Fig.3.1 and Fig.3.2.

Table 2: Whiteness Index of untreated and treated (H_2O_2) cotton samples

Conditions of Ultrasonic Bath (Temperature, Time)	Fibre (A) W	Yarn (A) W	Fibre (B) W	Yarn (B) W
Untreated sample	34.8	23.0	39.2	19.0
20°C, 30 min	53.6	29.8	49.6	34.0
20°C, 60 min	56.3	32.7	51.7	36.3
40°C, 30 min	57.2	36.5	55.2	40.0
40°C, 60 min	58.6	41.8	56.6	41.8
(%) of increase in whiteness index	68	82	44	120

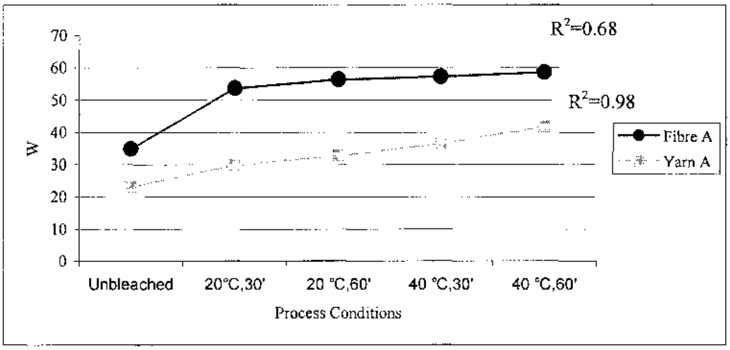

Fig 3.1. Whiteness Index of Cotton (A) Samples

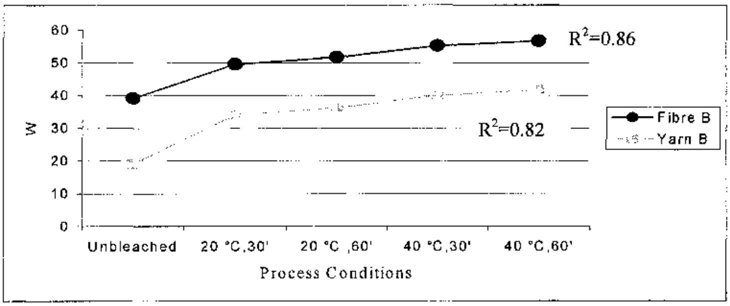

Fig. 3.2 Whiteness Index of Cotton (B) Samples

As can be seen from both Fig.3.1 and Fig.3.2 whiteness of cotton samples improved by increasing both the temperature and the time. Also cotton fibres show higher whiteness than the yarns.

Percentage increase in both yarns have shown higher results than their fibre data (see Table 2). However, the finer cotton fibre samples (A coded) have presented higher increment than the coarser one.

Main improvement of the whiteness can been seen at the lower temperature and at the minimum time of ultrasonic bleaching process. After that, improvement of the whiteness has occured slowly.

STATISTICAL ANALYSIS

To be able to give a clearer picture of understanding of the effect of ultrasonic bleaching process just one of the sample (cotton fibre **A** and ring-spun yarn **A**) was also analysed by the factorial design technique (D8/3) using the MINITAB Release 13.32 software programme. The graphics of normal probability outcomes are shown in Fig.4.1, main effects are given in Fig.4.2, interactions are also shown in Fig.4.3.

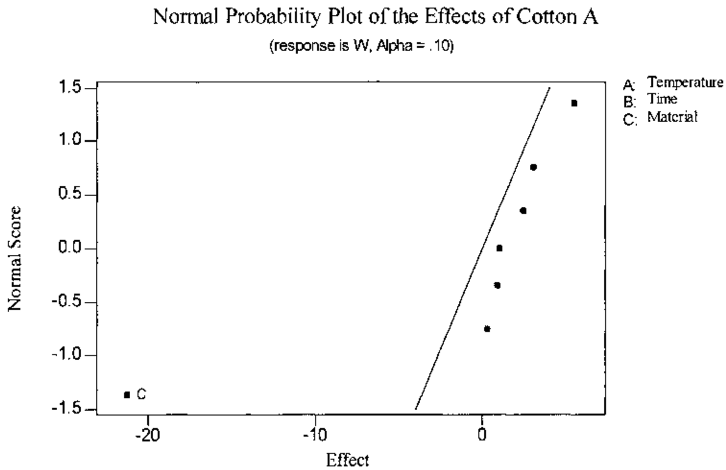

Fig.4.1 Effect of Temperature, Time and Material on Ultrasonic Bleached Cotton A

As seen from both Fig 4.1 and Fig 4.2, material's effect is much more important than temperature and time.

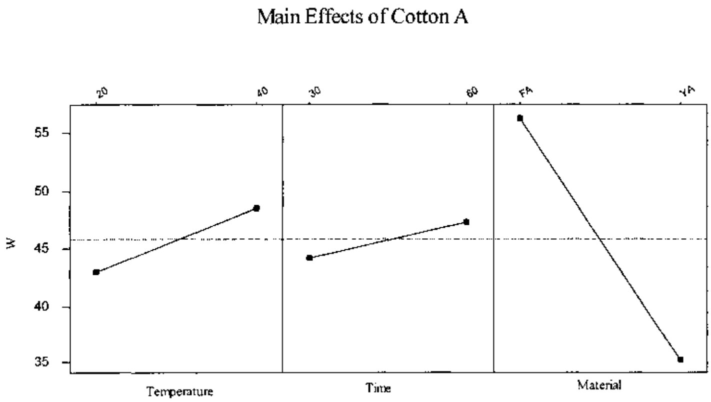

Fig 4.2 Main Effects on the Ultrasonic Bleaching

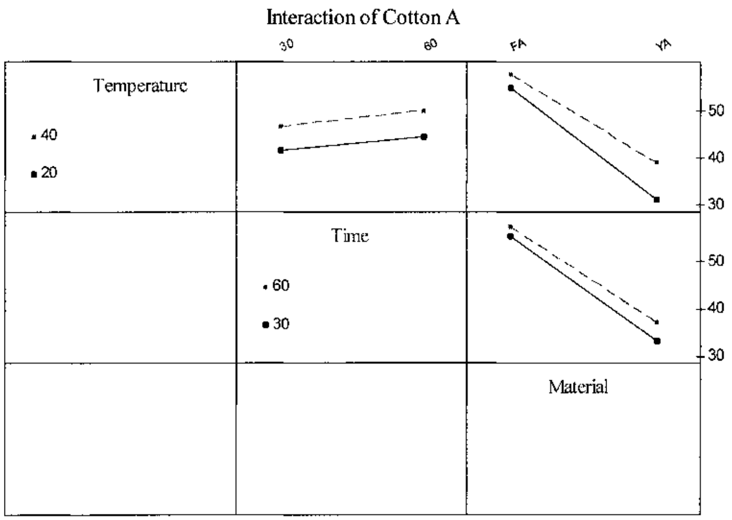

Fig.4.3 Interaction Effects on the Ultrasonic Bleaching

There is no significant interaction effects on the whiteness index of the materials (see Fig.4.3).

Contour plottings of the fibre A and ring-spun yarn A are given in Fig.4.4 and Fig.4.5 .

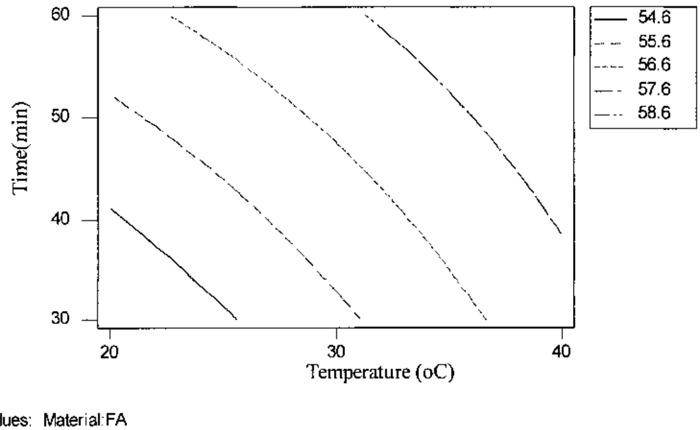

Fig.4.4 Effect of Temperature and Time on the Whiteness of the Cotton Fibre A

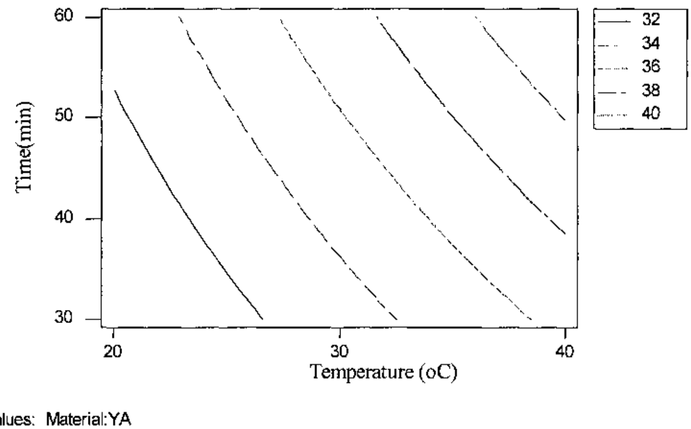

Fig.4.5 Effect of Temperature and Time on the Whiteness of the Cotton Yarn A

As can be seen from Fig 4.4 and Fig 4.5, the whiteness of the cotton fibre and the whiteness of the cotton ring-spun yarn increases as both temperature and time are increased.

CONCLUSIONS

1. There is a good correlation between whiteness index and ultrasonic bleaching processes of the cotton fibres and cotton ring-spun yarns.
2. Whiteness of unbleached cotton fibre is higher than the unbleached cotton ring-spun yarn. This situation also exists after the ultrasonic bleaching.
3. Both fibre and yarn specimens of cotton become whiter as temperature and time are increased during the ultrasonic process.

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A STUDY OF THE PREVALENCE OF RESPIRATORY MORBIDITY IN THE WORKERS OF TEXTILE INDUSTRY OF BARODA CITY

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ABSTRACT

Background: Byssinosis caused by inhalation of vegetable dust (Cotton, Flax, Soft hemp) is a continuing problem and occurs worldwide.
Cotton production and use has expanded rapidly in developing countries. The characteristic "Monday Symptoms" are associated with changes in pulmonary functions.
The present study reports on the disease spectrum in a textile mill of Baroda city and is based on the WHO grading system.

Objectives:

* To measure acute and chronic changes in pulmonary functions due to exposure to cotton dust.
* To find out the prevalence of byssinosis in textile workers.

Methodology: A cross-sectional study was carried out in different departments of a textile mill of Baroda city and healthy controls for assessment of acute and chronic changes in ventilatory functions and prevalence of Byssinosis due to exposure of cotton dust. A standard questionnaire was administered and pre and post shift lung function tests were measured for each worker.

Results: The study shows that 16.25 per cent of those exposed had byssinosis while no case was detected in the control group. 20% male workers showed various types of chronic changes in FEV_1 as compared to 10% male controls. 57 per cent Byssinotics (symptomatics) as compared to 10 per cent non-byssinotics (non-symptomatics) revealed chronic changes in lung functions of mild to severe category ($P<0.001$) and also higher percentage (80.9 per cent) of byssinotics as compared to non-byssinotics (58.3 per cent) revealed mild to severe category of acute change ($P<0.005$).

Conclusion: in brief the study indicates that cotton dust is potent respiratory irritant and the workers are occupationally exposed to pulmonary hazards in their work environment and that merits attention.

Key Words: Byssinotics, Non-byssinotics, Acute change, Chronic change.

INTRODUCTION

Byssinosis caused by inhalation of vegetable dust (cotton, flax, soft hemp) is a continuing problem and occurs worldwide.

Cotton production and use has expanded rapidly in developing countries. Byssinosis is characterized by symptoms of chest tightness and/or shortness of breath on returning to work after an absence[1].

The characteristic "Monday Symptoms" are associated with changes in pulmonary function tests. Recognition of byssinosis as an occupational lung disease has been delayed mainly because of the absence of characteristic physical and X-ray signs indicating pathological changes in the lungs until the lung function tests became available.

The clinical grading system of Schilling[2] has been used widely in many countries. A lung function grading system has been used in addition to clinical grading based on changes in FEV_1 (Bouhuys)[3]. The functional grading comprises of measurement of acute effects of dust exposure during work-shift and chronic effects with irreversible impairment of ventilatory capacity.

A number of studies have documented the acute and the chronic effects of cotton dust on pulmonary functions.[4,5,6,7,8] The prevalence of byssinosis among textile workers and locations of early changes have been described by many studies. [3,5,9,10,11,12,13,14]

The present study reports on the disease spectrum in a textile mill of Baroda city and is based on the WHO grading system.[1]

OBJECTIVES

- * To measure acute and chronic changes in pulmonary functions due to exposure to cotton dust.
- ** To find out the prevalence of byssinosis in textile workers.

MATERIALS AND METHODS

A cross-sectional study was conducted during October 1993 to October 1994 in different departments of a textile mill in Baroda city.

The textile mill studied has been functioning in three shifts for 55 years and manufactures pure cotton thread for Dhoti. The sections functioning are blow room, card room, spinning and winding; the workers' strength being 200 in blow room, card room and spinning sections and 70 in winding section.

Study consisted of 130 workers exposed to cotton dust from blow room, card room, spinning and winding departments of a textile mill, and 130 healthy controls from Class IV staff of Medical College, Baroda. A standard questionnaire on respiratory symptoms Schilling's[16] was administered to all the workers and their lung functions were recorded after a weekend holiday (Tuesday) of the first shift at 7.00 a.m. (pre shift) and 2 p.m. (post shift) to record acute and chronic changes. In all these workers occupational history and physical findings were noted. All the workers were interviewed and examined by the first author who had no previous knowledge of the worker's section and health state.

Morgan Electronic Pocket Spirometer was used to record forced expiratory volume in one second (FEV_1), peak expiratory flow rate (PEFR) and forced vital capacity (FVC) for each worker expressed at BTPS level. All the recordings were made three times and the best one was used for analysis. The functional values were compared between control and exposed workers.

Acute and chronic changes in FEV_1 and PEFR were recorded using WHO classification.[1] For observing chronic effects predicted values (P) were calculated using formula of Kamat.[17] On the basis of data obtained the diagnosis of byssinosis was made and the disease was graded according to WHO classification.[1]

Environmental Assessment:

The dust sampling was carried out by using a vertical elutriator specifically designed to collect cotton dust. The design required a flowrate of 7.4 lpm and particles less then 15u in size were sampled. 2 hour samples were taken from two sections. One near the Willow machine (blow room) and other from spinning section. Dust sampling was carried out by Industrial Hygiene Laboratory (IHC), Ahmedabad on 1st May 1994.

Lung function tests of exposed (byssinotics and non-byssinotics) were compared using Student's 't' test. All the parameters of PFTs were compared in both the groups, mean values of PFTs in exposed were compared with control group similarly. Chronic changes in lung functions were compared between byssinotics and non-byssinotics by applying X^2 test. Relative risk (RR) has been also calculated for comparing the acute changes between byssinotics and non-byssinotics.

It was originally decided to study all the employees working in dusty sections i.e. blow room, card room and spinning. However, during the study, workers become aware of the problems and those having the disease started enquiring about treatment and their right of compensation from the management. As byssinosis is a compensable disease, the management of the mill, later in the study did not co-operate well, resulting in examination of 40 per cent of spinners. This may have affected the crude prevalence depending upon the department specific prevalence rate. The crude prevalence rate is 16.15 per cent, it would have been slightly less if all the spinners were studied, as most of the symptomatics volunteered in the study first.

RESULTS

Table 1 – Distribution Of Exposed Workers In Different Departments Of Textile Mill

Type of Department	Male (M)	Female (F)
Blow Room		
Number	10	0
Percent	(10)	
Card Room		
Number	13	0
Percent	(13)	
Spinning		
Number	77	0
Percent	(77)	
Winding		
Number	0	30
Percent		(100)
Total		
Number	100	30
Percent	(100)	(100)

Table 2 – Prevalence of Different Grades Of Byssinosis*

Grading of Byssinosis*	Male N = 100	Female N = 30	Total N = 130
½			
Number	04	0	04
Percent	(04)		(3.07)

I.			
Number	06	0	06
Percent	(06)		(4.61)
II.			
Number	05	0	05
Percent	(05)		(3.84)
III.			
Number	06	0	06
Percent	(06)		(4.61)
Total all grades			
Number	21	0	21
Percent	(21)		(16.15)

* Schilling's Classification of Byssinosis WHO 1993

Overall all prevalence of byssinosis is 16.15%. no case was found in winding section where only females were working. Also no case was detected in the control group.

Table 3 - Chronic Changes In FEV_1 In The Subjects Departmentwise

Chronic Change + (% PRED FEV_1)	Controls		Exposed				
	Males N=100	Females N=30	Blow Room N=10	Card Room N=13	Spinning N=77	Total N=100 (M)	Winding N=30 (F)
Normal N	90	26	08	08	64	80*	27
%	(90)	(86.66)	(80)	(61.53)	(83.11)	(80)	(90)
Mild to Moderate N	09	04	01	05	10	16	03
%	(09)	(13.33)	(10)	(38.46)	(12.98)	(16)	(10)
Severe N	01	00	01	00	03	04	00
%	(01)		(10)		(03.90)	(04)	

\+ Chronic changes as per WHO classification $X^2 = 3.92$ $P<0.05$ df_1

Relative Risk (RR) = 2 (Males), 1.33 (Females) Attributable Risk (AR) = 50%.
It is seen that 20% male workers are showing various types of chronic changes (impairments) in FEV_1 (16% mild to moderate and 4% severe) as compared to 10% male controls (9% mild to moderate, 1% severe)

Table 4 – PFT Values In Byssinotics And Non-Byssinotics

Parameters	Exposed (M) N = 100			Controls (M)
	Byssinotics N = 21	Non-Byssinotics N=79	Total N = 100	N =100
FVC (Litres) Observed (OB) M ± SD	2.45±0.69	3.00* ±0.72	2.89±0.75	3.04±0.85
Predicted (Pred) M + SD	3.00±0.40	2.99±0.44	2.99±0.43	3.38* ±0.50
Percent Pred M ± SD	82.77±22.35	101.22* ±21.05	97.35±22.99	89.16±19.19

FEV_1 Litres Observed (OB) M $\pm$ SD	1.74$\pm$0.62	2.48$\pm$0.58*	2.32$\pm$0.66	2.75$\pm$0.78*
Predicated (Pred) M $\pm$ SD	2.29$\pm$0.36	2.30$\pm$0.42	2.29$\pm$0.41	2.70$\pm$0.46*
Percent pred M $\pm$ SD	75.65$\pm$22.04	109.32$\pm$22.10	101.38$\pm$25.96	101.57$\pm$18.59
FEV_1 Percent Observed (OB) M $\pm$ SD	72.48$\pm$17.83	83.80$\pm$14.97*	81.42$\pm$16.28	91.28$\pm$11.35*
PEFR (Lit/Sec) Observed (OB) M $\pm$ SD	232$\pm$101.01	347.49$\pm$95.61*	323.28$\pm$107.56	439.18$\pm$241.32*
Predicated (Pred) M $\pm$ SD	477.62$\pm$37.88	478.68$\pm$43.31	478.46$\pm$42.23	519.75$\pm$48.48*
Percent Pred M $\pm$ SD	48.64$\pm$20.95	72.91$\pm$19.15	67.82$\pm$21.90	84.50$\pm$40.66

*Indicate Significant Values (P<0.01).

There is significant reduction (P<0.01) in FEV_1, FEV_1 % and PEFR in exposed workers. Further in byssinotic workers there is significant reduction (p<0.01) in all the parameters (FEV_1, FVC, PEFR and FEV_1%) as compared to non-byssinotic workers.

Table 5 – Chronic Changes* In FEV_1 And PEFR In Byssinotics & Non-Byssinotics

Chronic Changes*	Byssinotics N = 21		Non-Byssinotics N = 79	
	FEV_1	PEFR	FEV_1	PEFR
Normal				
Number	9	1	71	23
Percent	(42.86)	(4.76)	(89.80)	(29.11)
Mild to Moderate				
Number	8	5	8	39
Percent	(38.09)	(23.81)	(10.10)	(49.37)
Severe				
Number	4	15	0	17
Percent	(19.05)	(71.43)		(21.52)

* Chronic changes as per WHO classification

FEV_1 $X^1 = 22.9$ $P < 0.001$ df:1 PEFR $X^2 = 5.3$ $P < 0.05$ df:1

57.14% (12/21) of byssinotic workers are showing chronic changes in FEV_1 as compared to 10.1% (8/79) of non-byssinotics (P<0.001). When PEFR is compared 95.23 % (20/21) of byssinotic workers are showing chronic changes (23.81% Mild to moderate, 71.43% severe) as compared to 70.89% (56/79) of non-byssinotic.

Both FEV_1 and PEFR (P<0.05) are affected due to exposure to cotton dust. Among the byssinotics and non-byssinotics, the percentage of various types of chronic changes in PEFR are more than that seen in FEV_1..

Table 6 – PFT Values In Byssinotics & Non-Byssinotics Pre And Post-Shift (Acute-Change)

PFT	Pre-shift Value	Post-shift Value	Shift Difference (Post-pre)	% Shift Difference
FEV_1 (OB) Byss. (M) M + SD N = 21	2.24±0.55*	1.74±0.62	-0.50±0.42*	-22.32±9.97
Non-Byss.(M) M + SD N = 79	2.48±0.58*	2.29±0.52	-0.19±0.30	-7.66±9.92
PEFR (OB) Byss. (M) M + SD N = 21	313.61±118.98*	232.19±101.01	-81.42±53.17	-25.96±13.22
Non-Byss.(M) M + SD N = 79	347.49 + 95.61*	02.15±115.43	-45.34 + 33.16	-13.05 + 13.07

* Indicate significant values ($P < 0.05$) (-) Decreased values

The post-shift values of FEV_1 and PEFR are significantly reduced ($P<0.05$) in both byssinotics and non-byssinotics. When FEV_1 and PEFR are compared in byssinotics and non-byssinotics, significant reduction ($P<0.05$) is observed in byssinotics as compared to non-byssinotics.

Table 7 – Acute Changes* In FEV_1 And PEFR In Non-Byssinotics And Byssinotics

Acute Changes*	FEV_1			PEFR		
	Byss. N =21 (M)	Non-Byss N = 79 (M)	Non-Byss N = 30 (F)	Byss N=21 (M)	Non-Byss N=79 (M)	Non-Byss N=30 (F)
Normal						
Number	04	33	09	04	24	08
Percent	(19.04)	(41.77)	(30)	(19.04)	(30.37)	(26.66)
Mild						
Number	07	21	11	04	25	09
Percent	(33.33)	(26.58)	(36.66)	(19.04)	(31.64)	(30)
Moderate						
Number	06	15	08	10	14	07
Percent	(28.57)	(19.98)	(26.66)	(33.33)	(17.72)	(23.33)
Severe						
Number	04	10	02	03	16	06
Percent	(19.04)	(12.65)	(06.66)	(10)	(20.25)	(20)

* Acute changes as per WHO classification

80.96% (17/21) byssinotic workers show mild to severe changes in FEV_1 and PEFR, RR=1.37 ($P<0.05$), both the parameters being equally affected. While in case of non-byssinotics 69.63% show mild to severe changes in PEFR and 58.33% in FEV_1 and, PEFR shows greater reduction as compared to FEV_1. Though females were non-byssinotics, 70% showed acute changes in FEV_1 and 73.33% in PEFR.

Table 8 – Dust Concentration In Different Sections Of The Cotton Textile Mill

Section	No. of Samples	Total Dust Mg/m^3	Time	Prevalence of Byssinosis (all grades) No. (%)
Blow Room	1	31.1	(2 Hrs.) 3.25 PM To 5.25 PM	2/10 (20)
Spinning	1	22.4	(2 Hrs) 3.35 PM To 5.35 PM	12/77 (15.60)

Threshold value $1.0/m^3$ as recommended by ACGIH[18]

Near blow room the dust level is high as compared to spinning section. Both the values are quite high as compared to the Threshold Limit Values recommended for cotton dust by the American Conference of Government Industrial Hygienists[18] (ACGIH). This also corresponds to high prevalence of byssinosis in blowers (20%) as compared to spinners (15.6%).

DISCUSSION

Byssinosis is an occupational hazard for workers exposed to cotton dust, severity of disease varying from being symptomatic only after the weekend holiday to disability even at rest. The present study reveals 16.15 per cent prevalence of byssinosis which is more as compared to other Indian studies [11,15,17] but low as compared to Schilling[2]. None of the females working in winding section suffered from byssinosis. Possible reasons include winding section being less dusty, females using face masks and wetting system observation in this section. The high prevalence of the disease is due to poor working conditions and high dust levels as compared to the Threshold Limit Value (20 times TLV). The working rooms are poorly ventilated and cotton fibres float freely in the working environment. Further very few workers used protective face masks.

The chronic changes in FEV_1 and PEFR also revealed higher prevalence of impairment of mild to moderate degree in byssinotics as compared to non-byssinotics, which is similar to other studies. [4,5,8,19,23,24,25] The chronic effect on PEFR is seen and is higher as compared to FEV_1 in byssinotics and non-byssinotics. Other studies [26,27] also observed that, in addition to FEV_1 in clinical classification of lung function grading, changes in PEFR also are taken into account as PEFR is known to highly correlate with FEV_1 as a measure of ventilatory capacity. This study results indicate significant reduction in FEV_1 and PEFR in byssinotics as compared to non-byssinotics on acute exposure to cotton dust over the first working day after weekend.

Female workers from winding section who were symptom-free showed mild to moderate acute changes.

Acute measures for the reduction of dust levels need to be introduced in these departments as a priority.

LIMITATIONS

This is a cross-sectional study conducted in a single textile mill; workers had different years of work experience. Hence the possibility of survival bias in the study cannot be ruled out. So the inference needs to looked into after keeping the above factors in mind. Respirable dust could not be determined as the instrument for the same was not available.

RECOMMENDATIONS

1. Medical measures: Pre-employment examination, retesting of newly employed workers for ventilatory capacity within 6 weeks on first day of work (after 40 hours absence from exposure) pre-shift and post- shift should be carried out.
   Those having predicted value of FEV_1 < 80 per cent and acute change >5 per cent should be re-evaluated after 6 months and those having FEV_1 <60 per cent and acute change >10 per cent should be excluded from exposure. All workers should be offered medical examination and PFT yearly thereafter.
2. Engineering methods: There is a need to prevent dust of respirable size by good house-keeping and adequate use of appropriate exhaust system. Evaluation of workplace conditions every 6 months and environmental monitoring with regard to dust standards of ACGIH[18] is advisable.
3. Statutory methods: Standards set by governmental agencies for acceptable levels of dust concentration and enforcement of the same. Notification of disease of earlier stages also.
4. Further Research: Including a nation-wide survey of textile mills with special reference to disease in non-smokers is suggested. The need for an effective control programme is suggested to see that byssinosis suspects are properly examined and given proper treatment.

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MARKET RESEARCH AND OVERVIEW OF TURKISH HYGIENIC PRODUCTS

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ABSTRACT

In this research all the hygiene products currently sold in the Turkish market have been investigated. All exports and imports with countries of origin and volumes have been studied. Market capacity is also researched and the results are discussed.

INTRODUCTION

Nonwovens are the most widely used materials in single use textiles globally. Hygienic products take the lead in single use products in the markets of the world. Hygienic products include babies diapers, ladies sanitary towels and adult incontinence pads for the elderly and consist of over 35 billion US dollar market.

Table 1 World Hygienic Product Markets And Estimated Developments

Nonwoven Containing Single -use Hygienic Product End-uses	World Market Volume	Estimated Increase In World Market
Diapers	$ 19 Billion	9%
Adult Incontinence	$ 4.5 Billion	8-30%
Ladies Sanitary Products	$ 12 Billion	America & Western Europe 2%, Asia & Eastern Europe 10-15%

In the 1980's Turkey was importing hygienic products, however, towards the end of the 1980's Turkey started to produce its own hygienic products and has developed into a sector with around a $300 million market share.

In this paper the Turkish hygienic products market has been researched. It should be noted that research has been carried out on two main products baby's diapers and ladies hygienic pads (sanitary products). All the names of the firms in the market, development of capacity, imports and exports, estimated internal and external demands; internal market volume figures are discussed. Daily use of panty liners and Incontinence pads are not taken in to account in this work due to the lack of information about these products.

TURKISH HYGIENIC PRODUCT MARKET

There are 16 companies involved in the production of hygienic products in Turkey. The names, dates of production, commencement of place of production and product names are given in Tables 2 below. It can be seen in Table 2 that production started in late 1980's in Turkey.

Table 2 Companies Producing Babies Diapers and Hygienic Ladies Pads in Turkey

	FIRMS	Date of Start of Bussiness	Place of	Product (*)	Name of Products
1	PROCTER GAMBLE Tüketim Malları San. A.Ş.	1990	Kocaeli	BD LSP dHP	Prima, Pampers Orkid Orkid-Yaprak, Alldays
2	ASTEL Kağıtçılık San ve Tic. A.Ş.	1990	Istanbul	BD LSP AI	Canbebe, Bello Canleydi Canped, VVİndelhosen
3	TOPRAK ilaç ve Kim. Mad. San. Tic. A.Ş.	1996	Sakarya	BD LSP	Libero, Nova [illegible]
4	HAYAT Kimya San. ve Tic. A.Ş.	1998	Istanbul	BD LSP	Molfix, Bebem Molped
5	ROZI Kağıt. Tem. Ur. San. ve Tic. A.Ş.	1997	Istanbul	BD LSP	Rozı, Lılibebe Rozi, Yes
6	ELHADEFLER Kağıtçılık San. ve Tic. A.Ş.	1989	Istanbul	BD LSP dHP AI	Lila, lilafiks
7	PAKSEL Kimya San. ve Tic. A.Ş.	1992	Tekirdağ	BD	Bebiko, Diana
8	OZBEY Hijyenik Ürünler San. ve Tic. A.Ş.	2001	Karaman	BD	Elbebek, Albodo
9	YUZAL intern. Tic. ve San. A.Ş.	2001	Istanbul	BD LSP	Pomiks, Babyline Pomiksped
10	OVİSAN Sıhhi Bez San. ve Tic. A.Ş.	1989	Istanbul	BD	Pedo
11	FANY SOFT Kağıt San. Ltd. Şti.	1993	Adana	BD	Fany, Bebeteks
12	IDA Kim. ve Sıh. M d. Paz. San. ve Tic.	1998	Yalova	BD	Bambola, Gülenbebe
13	PAKTEN Sağlık Ürü. ve Tic. A.Ş.	2000	Gaziantep	BD	Joyfui, Önlem
14	İŞSEVEROĞLU iplik Tic. San. A.Ş.	2000	Adana	BD	Samo, Deyzı
15	AAK Gıda San. Dış Tic. A.Ş.	2001	Kırklareli	BD	Markasız
16	HES Kimya San. ve Tic. A.Ş.	2002	Kayseri	LSP	Polped, Notped

(*) **BD**: Babies Diapers **LSP**: Ladies Sanitary products **dHP**: Daily Ladies Sanitary (Panty Liners) **AI**: Adult Incontinence

In Table 3 existing capacity and estimated growth figures of production are given.

Table 3 Sectors of Babies Diaper and Ladies Sanitary Products Capacity Development (000.units)

YEAR		EXISTING CAPACITY	ADDED CAPACITY	TOTAL CAPACITY
2002	BD	2.772.630	170.100	2.942.730
	LSP	1.168.020	181.440	1.349.460
2003	BD	2.942.730	170.100	3.112.830
	LSP	1.349.460	748.440	2.097.900
2004	BD	3.112.830	107.000	3.219.830
	LSP	2.097.900	60.300	2.158.200

Table 4 below lists the companies in order of volume of production. As it can be seen Procter and Gamble are the largest producer in Turkey. All the rest of the companies arc of Turkish origin.

Table 4 Companies Listed by Order of Volume of Production

Year	BD Producers in Order of Volume	LSP Producers in Order Of Volume
2001	Procter Gamble A.Ş	Procter Gamble A.Ş
	Astel A.Ş	Astel A.Ş
	Ovisan A.Ş	Toprak A.Ş
	Rozi A.Ş	Rozi A.Ş
	Hayat A.Ş	Hayat A.Ş
2002	Procter Gamble A.Ş	Procter Gamble A.Ş
	Astel A.Ş	Toprak A.Ş
	Ovisan Ş	Ovisan A.Ş
	Hayat A.Ş	Hayat A.Ş
	Rozi A.Ş	Rozi A.Ş

In year 2000, Procter and Gamble produced the most BD followed by Astel, Ovisan, Rozi and Hayat. In HP however after P&G(Proctor and Gamble), Astel takes the second place followed by Toprak, Rozi and Hayat.

In year 2002 when the BD production is evaluated, there was a reduction in P&G production, where as Astel stayed the same and Ovisan, Hayat and Rozi increased their production. In HP, in 2002 again there was a reduction in P&G production rate and increase production of Astel, Rozi and Hayat.

Daily used Panty Liners (dHP) are believed to constitute 14-15 % of the total HP in Turkey. Due to the increase in competition in the domestic market, companies have started to look to the exportation of their products. In recent years exportation of Hygienic Products in Turkey has increased.

Turkish Hygienic Product exports are mainly concentrated in three areas;

USR
Balkan Countries
South Africa and Israel

The above countries constitute the largest part of Turkish hygienic products exports However apart from exports to the above-mentioned countries exports to African countries and the Central Asian Turkish Republics are also slowly increasing.

Table 5 Outline the Turkish HP Exports Volume (kg) and Value ($)

YEARS	BD		LSP	
	Volume(kg)	Value($)	Volume(kg)	Value($)
1994	319.012	786.434	28.328	133.565
1995	734.553	1.795.932	690.487	2.499.672
1996	1.334.455	3.838.470	365.800	1.078.675
1997	4.353.289	11.133.270	1.509.023	4.498.565
1998	3.028.021	7.569.380	2.133.598	8.533.617
1999	5.503.118	13.217.063	1.505.737	6.439.944
2000	4.673.643	11.626.595	1.926.170	11.317.285
2001	15.391.095	34.805.120	2.193.234	13.233.995
2002 *	22.219.309 !	44.873.903	3.470.536	14.664.169

(*) Include January-October

Table 6 Turkish Export Distribution of Babies Diapers and Ladies Sanitary Products in Volume (Kg) by Countries

	COUNTRIES	2001		2002 *	
		BD	LSP	BD	LSP
1	Azerbaian	352.159	98.468	328.993	72.631
2	Bulgaria	448.707	20.270	1.510.588	20.248
4	South African Rebuplic	3.261.889	94.362	3.670.039	1.584.937
5	Georgia	750.047	152.896	590.721	123.915
6	Israel	3.518.592	185.051	4.596.279	327.062
7	Italy	-	-	1.341.238	-
8	Kazakhistan	807.737	212.642	56	4.996
9	Lebonan	60.884	481	232.841	-
10	Hungary	664.715	84.905	47.106	125.483
11	Macedonia	1.180.891	734	1.683.725	71.144
12	Poland	345.436	150.412	-	30.925
13	Romania	2.115.023	106.476	4.848.126	5.447
14	Russia	232.950	224.780	13.854	167.500
15	Ukraine	40.254	97.023	53.159	113.747
16	Jordan	267.085	-	276.845	-
17	Yugoslavia	535.894	255	536.082	1.043
18	Free Zones	171.934	370.357	530.826	504.859
19	Unknown	266.696	48.496	313.267	37.411
	19 COUNTRIES TOTAL	15.020.893	1.847.608	20.573.745	3.191.348
	OVERALL TOTAL	15.391.095	2.193.234	22.219.309	3.470.536

(*) Include January-October

When the trend of exports is evaluated it can be clearly seen that the largest markets of Turkish babies diapers are Israel, South Africa, Romania and Macedonia however in ladies sanitary products the biggest importers are South Africa, Israel and Russia. Table 6 outlines the Turkish Hygienic Product exports by countries.

Table 7 Turkish Babies Diapers and Ladies Sanitary Export ($)

YEAR	BD		LSP	
	Volume	Value	Volume	Value
1994	45.851	163.297	95.283	336.077
1995	1.349.596	4.891.090	263.440	1.845.787
1996	3.002.583	8.136.324	722.860	4.135.202
1997	2.096.886	5.249.514	1.434.230	7.553.259
1998	1.295.958	3.370.729	823.017	4.904.056
1999	2.209.012	5.394.006	1.073.561	5.858.607

2000	4.678.848	10.992.530	1.132.352	5.758.931
2001	2.575.765	5.386.182	1.167.942	6.150.286
2002 *	984.654	2.088.628	1.519.964	7.551.982

(*)Include January-October.

When export of babies diapers products of Turkey are investigated both positive and negative trends over the years can be observed. The highest export was at year 2000 with 4679 tonnes and the lowest export was in the year 2002 at levels of 985 tonnes. However increasing trends were observed in ladies sanitary products year after year.

Table 8 shows the Turkish hygienic product exports by country.

Table 8 Babies Diapers and Ladies Sanitary Product Exports By Countries In Volume

		2001		2002*	
	COUNTRIES	**BD**	**LSP**	**BD**	**LSP**
1	Germany	285.002	-	135.655	294.276
2	USA	-	-	270	
3	Belgum	357.401	40.424	302.000	14.386
4	Bulgaria		-	87	5.781
5	Czech Rebuplic		68.973		-
6	China	-	-	-	5.930
7	Indonezia		-	-	54.842
8	France		-	67.317	-
9	Holland	-	525	-	-
10	England	3.064		354	-
11	Espania	-	1.750	-	20.572
12	Israel	1.359.874		456.685	47.450
13	Sweden	-	-	-	-
14	Swiss	-	12.422	18.000	3.414
15	Italy	55.867	185.724	3.940	242.452
16	Hungary	-	858.124	-	830.861
17	Polanda	514.553	-	-	-
18	Romania	4	-	-	-
19	Taiwan	-	-	346	-
	OVERALL TOTAL	2.575.765	1.167.942	984.654	1.519.964

(*)Include January-October.

Hygienic Ladies Sanitary Products imports to Turkey are given in Table 9 in terms of product name and name of the producer.

Table 9 Imported LSP and Producers

	COMPANY NAME	**PRODUCT**	**PRODUCT NAME**
1	JOHNSON and JOHNSON	LSP, Tampon dHP	Carefree, Stayfree, O. B. Carefree
2	OVISAN	LSP dHP	Kotex Kotex
3	LRC PRODUCT	Tampon	Tampax
4	PROCTER GAMBLE	Tampon	Tampax

Table 10 Turkish Babies Diapers and Ladies Sanitary Export and Import by Volume (units)

	BD		LSP	
YEAR	EXPORT	IMPORT	EXPORT	IMPORT
1994	6.897.557	991.373	3.848.913	12.946.060
1995	15.882.227	29.180.454	93.816.168	35.793,478
1996	28.853.081	64.920.714	49.701.087	98.214.674
1997	94.125.168	45.338.076	205.030.299	194.868.207
1998	65.470.724	28.020.714	289.891.033	111.822.962
1999	118.986.335	47.762.422	204.583.832	145.864.266
2000	101.051.741	101.164.281	261.707.880	153.852.174
2001	332.780.432	55.692.216	297.993.750	158.687.772
2002 (*)	480.417.492	21.289.816	471.540.217	206.516.848

(*)Include January-October.

In the foreign trade, values are kept in volume (kg) by the Department of Outside Foreign Trade in Turkey. To be able to compare the Turkish babies diapers and sanitary products imports and exports the volumes need to be converted into single units. Assuming all the exports and imports of hygienic products are only babies diapers and ladies sanitary products and approximate weight of one diaper is 46.25g and sanitary product is 7.36g.Table 10 compares the Turkish exports and imports between 1994 and 2002.

To increase the exports new markets especially those with higher birth rates should be approached. Table 11 outlines the birth and death rates of the Middle Eastern countries.

Table11 Population Data In Middle Eastern Countries

Country	Population (millions)	Birth rate per 1000 population	Infant Mortality per 1000 births	Net live births	Theoretical Diaper Requirements
Saudi Arabia	22,023, 506	3747	52.90	781,560	3,321,630
Syria	16,305,659	31.1 1	34.86	489.606	2,080,825
Jordan	4,998,564	26.24	21.1 1	128,382	545.623
Yemen	1 7,479,206	43.44	70.28	705,946	5-45.623
Israel	5,842,454	1932	790	111,974	475.889
Egypt	68,359,979	25.38	62.32	1,626,652	6,914,121
Turkey	65,666,677	18.65	48.90	1,164,835	4.950,549

CONCLUSIONS

Turkey was a hygienic product importer till the late 1980's. Since the late 1980's the Turkish hygienic product sector has grown rapidly and has started to produce for the internal market. After fulfilling the internal market in the second half of the 1990's Turkish hygienic product exports started to increase steadily. Turkey also imports hygienic products but the imports do not show the same trends as exports.

There are 16 companies producing hygienic products in Turkey excluding the small non-brand producers.

The main markets for Turkish hygiene products are Israel, South Africa and Balkan countries. Main imports are from Israel, Benelux countries and Germany.

However Turkish hygienic products exports are increasing to Middle Eastern countries and Central Asian Turkic countries.

Turkey produces more than the internal demand and as a result the exports have increased. However Turkey should use its full capacity in hygienic products. That requires new markets. Capacity usage ratio of hygienic products in Turkey is believed to be 50%. Turkey therefore does not use its full capacity in hygienic products and is only using half. This is of course due to the market consumption and lack of export markets. Turkish hygienic product producers should look at the new markets to increase the exports to countries such as Middle East, North Africa, Central Asian countries and China. Birthrates shown in Table 11 prove this.

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