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Woodhead Publishing Series in Textiles: Number 100

Handbook of medical textiles

Edited by
V. T. Bartels



The Textile Institute

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**WOODHEAD
PUBLISHING**



Oxford Cambridge Philadelphia New Delhi

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Published by Woodhead Publishing Limited in association with The Textile Institute
Woodhead Publishing Limited,
80 High Street, Sawston, Cambridge CB22 3HJ, UK
www.woodheadpublishing.com

Woodhead Publishing, 1518 Walnut Street, Suite 1100, Philadelphia, PA 19102-3406, USA

Woodhead Publishing India Private Limited, G-2, Vardaan House, 7/28 Ansari Road,
Daryaganj, New Delhi – 110002, India
www.woodheadpublishingindia.com

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British Library Cataloguing in Publication Data
A catalogue record for this book is available from the British Library.

Library of Congress Control Number: 2011934929

ISBN 978-1-84569-691-7 (print)
ISBN 978-0-85709-369-1 (online)
ISSN 2042-0803 Woodhead Publishing Series in Textiles (print)
ISSN 2042-0811 Woodhead Publishing Series in Textiles (online)

The publisher's policy is to use permanent paper from mills that operate a sustainable forestry policy, and which has been manufactured from pulp which is processed using acid-free and elemental chlorine-free practices. Furthermore, the publisher ensures that the text paper and cover board used have met acceptable environmental accreditation standards.

Typeset by RefineCatch Limited, Bungay, Suffolk
Printed by TJI Digital, Padstow, Cornwall, UK

Cover image © Fotolia

Absorbent products for personal health care and hygiene

F. WIESEMANN and R. ADAM, Procter & Gamble
Service GmbH, Germany

Abstract: Products for baby and adult incontinence and feminine hygiene are important parts of daily life for millions of people around the world. The consumer needs, clinical performance and skin care requirements and technologies used in these products are similar across product categories; therefore, this chapter will cover a range of absorbent products used for personal health care and hygiene. It will explore the needs of patients and consumers, hygiene implications, testing methods, and the application of innovative technologies to products. Finally, we will discuss emerging trends in this field, and provide sources that may be of use to the reader interested in obtaining additional information.

Key words: adult incontinence products, superabsorbent baby diapers, feminine hygiene products, skin health, sustainability.

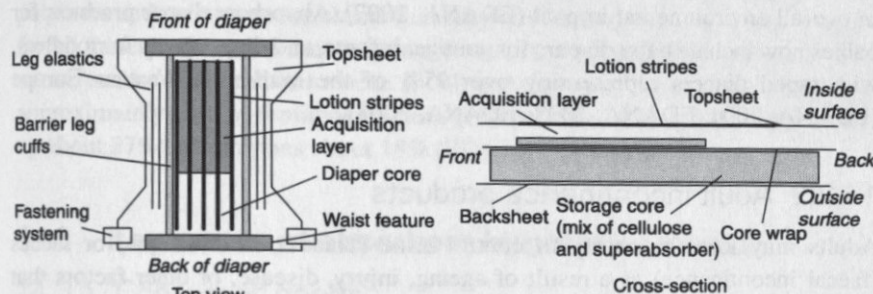
14.1 Introduction

Products for baby and adult incontinence and feminine hygiene are important parts of daily life for millions of people around the world. While the uses of these products range from areas of medical application, such as diapers for premature babies, children with enuresis, or incontinent adults, and consumer uses such as baby diapers or feminine hygiene products, the consumer needs, clinical performance and skin care requirements and technologies used in these products are similar across product categories. Because of these similarities, this chapter will cover a broad range of absorbent products used for personal health care and hygiene. It will explore the key needs of patients and consumers relating to absorbent products, hygiene implications of use, and textile properties and clinical testing methods employed during product development. We will illustrate the application of technologies using the example of a series of products designed for use in babies, from products for premature infants through toddler toilet training. Finally, we will discuss some emerging trends in this field, and provide sources that may be of use to the reader interested in obtaining additional information.

14.2 Different types of absorbent products for personal health and hygiene

The most commonly used absorbent products for personal health and hygiene are baby diapers, adult incontinence products, and feminine hygiene products.

Components of Hygiene Products (Example: Baby Diaper)



14.1 Diaper components.

Absorbent products in today's market are made up of a range of materials and component parts, which are adapted and optimised for the specific application in the different products. There are, however, some common elements across all products. All contain an absorbent core, which may be made up of cellulose or polymer fibres, superabsorbent polymer, or mixtures of fluff and superabsorbent polymers. Modern products, particularly more advanced products, may also make use of one or more acquisition or transport layers that help to quickly and effectively carry fluid into the absorbent core, while maintaining dryness against the skin. These acquisition layers are typically formed from synthetic staple fibres thermally bonded in a nonwoven structure, or a structure made up of chemically or mechanically modified cellulose fibres. The absorbent structures are embedded between a layer near the skin usually called a topsheet, which is made of polymer or natural fibres, and a backsheet of polyethylene film or a film/nonwoven composite ('textile backsheet'). The backsheet can be made of a microporous material to allow for vapour permeability or 'breathability'. Most importantly, the breathable backsheet reduces the relative humidity on the surface of skin in the diaper by allowing water vapour to pass outward. Typical components of disposable hygiene products are illustrated in Fig. 14.1.

14.2.1 Baby diapers

The first modern disposable baby diapers were introduced in the 1940s and mass production began in the 1960s. While these first disposable diapers were used primarily when away from home, demand for disposable diapers expanded rapidly during the 1960s and 1980s as they became more affordable for everyday use. Since the 1990s, a steady stream of technical innovations has improved the affordability, function, and comfort of diaper products, so that disposable diapers are now used much more commonly than reusable cloth diapers in most developed countries, including Western Europe and are becoming more popular in emerging nations. It is now understood that modern disposable diapers provide skin health

benefits (EDANA, 2008) compared to reusable cloth diapers, without an increase in overall environmental impact (EDANA, 2007). Absorbent diaper products for babies now include baby diapers for younger infants, and diaper pants for toddlers, with taped diapers representing over 95% of the market in Western Europe (EDANA, 2004; EDANA, 2007; EDANA, 2008).

14.2.2 Adult incontinence products

Adults may lose the ability to control urine (bladder incontinence) or faeces (faecal incontinence) as a result of ageing, injury, disease, or other factors that damage the nervous or muscular control needed to maintain continence. Common factors contributing to incontinence are pregnancy and childbirth, which can affect the strength of pelvic floor structures, and prostate surgery, which can damage nerves essential to control of urination. Adults who have become incontinent must struggle with both the physical aspects of dealing with the excreta and the social and emotional aspects relating to loss of dignity and fear that their condition may be betrayed to those around them by odour, leakage, or visibility of the incontinence product. In patients who are otherwise healthy and active, a discrete product allows the continuance of normal activities without fear of embarrassment. In patients with limited mobility or who are bedridden, use of an absorbent product that protects the skin from excreta is particularly important, as these patients are at high risk of skin breakdown and bed sores (EDANA, 2009, Quality of life brochure).

Adult incontinence products take a number of forms, and the best product for a particular user will depend upon a number of factors, including sex, type and degree of incontinence, and lifestyle. All wearable disposable products are now made with fluff and superabsorbent polymers, so that even small, thin products can contain large volumes of liquid and lock the liquid inside so that skin remains dry. Products include body worn all-in-one products (a taped product for severe faecal or urinary incontinence) and pads (worn as an insert in a special pant or in normal underwear, for light, medium, or severe incontinence), and male pouches (worn with an incontinence pant or tight underwear, for mild urinary incontinence).

14.2.3 Feminine hygiene products

In recent decades, disposable absorbent feminine hygiene products have largely replaced older methods of managing menses for women in the developed nations. Products include internal tampons, full-sized sanitary napkins or towels, both for use during menstruation, and panty shields, which may be used to protect undergarments from light menstrual flow or spotting or from vaginal discharge and to maintain cleanliness. In terms of their physical design and basic components, the most advanced sanitary napkins and panty shields make use of many of the

same technologies developed for use in baby diapers, including superabsorbent polymers and nonwoven top sheets that keep skin feeling dryer. The requirements for all these products are that they absorb and retain fluid, stay in place, prevent odour, and be comfortable to wear. In Western Europe, sanitary towels make up approximately 45% of feminine hygiene products sold, while panty shields make up about 37% and tampons about 18% (EDANA, 2004 data).

14.3 Key issues of absorbent hygiene products

14.3.1 Consumer needs

Specific consumer needs vary by user and type of product, but there are some consumer requirements for absorbent hygiene products that are common across categories. Users of baby diapers, adult incontinence products, and feminine hygiene products all require a product that facilitates cleanliness by absorbing and retaining fluid, protects the skin from damage due to exposure to excess moisture and digestive enzymes, does not leak, and is comfortable, convenient and discrete. Consumers also desire to use products that have minimal adverse effects on the environment. Advances in technology have led to the development of products that come very close to the ideal in many aspects, and work continues to better understand and address the needs of consumers who use disposable absorbent hygiene products.

Baby diapers

Consumer needs with regard to baby diapers are particularly diverse, as it is important to consider the needs of both the baby and the caregiver, and those needs may differ. For example, for a baby, the sensoric properties inside the diaper, like the dryness and the softness of the topsheet, play an important role in comfort during wear, while the mother may pay more attention to the absorbency and leak protection of the diaper. The diaper has to adapt to changing requirements over the course of a day (for instance, with activity during playtime versus less active phases during sleep), and to different needs as the baby grows and develops. Over time, the baby grows in size, capability, and activity level, and experiences changes in diet (from liquid to more solid food); each of these developments is associated with changes in the performance properties required of the diaper. Common needs across all stages of development include the need for superior urine absorbency, leak protection, dryness, and rash protection. Since their introduction in the 1940s, disposable diapers have evolved through a steady stream of product innovations, so that the best disposable diapers now offer very good containment of urine and faeces, along with excellent skin protection (Odio and Friedlander, 2000; Adam, 2008). Further efforts to improve these products include changes that improve the feel of the product during wear, make changing

easier, and adapt to the changing ability of the child to cooperate with changes and foster independence.

Adult incontinence

Adult incontinence occurs in both men and women and can range from light leakage of urine to complete loss of control of urine and faeces. The majority of adults with incontinence are women, and most of these experience light urinary incontinence. Consumer research has shown that many women use panty liners or sanitary napkins designed for menstruation to control small amounts of leakage because they are comfortable and discrete. Women with heavier leakage may use full-size sanitary napkins or pads specifically designed for female incontinence to achieve greater absorbency. Key consumer needs in this category include the need for protection/absorption (i.e., dryness, odour control, no leakage, no bunching), comfort/discretion (not bulky, acceptable feel while wearing, not noisy), a sense of being secure and in control (no social restrictions), and a need to forget about bladder weakness. Key incontinence product requirements are the ability to quickly acquire and store urine (which is more fluid, has lower viscosity, and is expelled under more pressure than menstrual fluid) and to deliver wearing comfort, as average wear time is between six and ten hours.

Feminine hygiene

Disposable absorbent products for feminine hygiene during menstruation are an important part of life for millions of women. The average woman will have approximately 13 cycles each year for about 37 years and will spend more than six years of that period menstruating. Menstrual flow varies with age, number of children, and use of hormones or intrauterine devices, and typically is heaviest during the second and third days of each period. Products include tampons, panty liners, and pads. Research has identified a number of consumer needs in this category, including the need to feel clean and dry, to be protected and in control, and for comfort and convenience. Key product performance requirements include the ability to handle a range of menstrual flows under a variety of use conditions and activities, to be friendly to skin and comfortable, and to be easy to use and to dispose of. The most advanced pads for menstrual protection make use of unique topsheets that funnel fluid into the absorbent core, maintaining a clean, dry feeling. The core of superabsorbent polymers rapidly absorbs moisture and locks it away, minimising leaks and controlling odour. Odour control can be done via different routes including slowing down odour generation by absorbing liquid and transferring it into a gel, using odour absorbent materials such as zeolithes, cyclodextrines or the like or inhibiting bacteria growth with chemical or natural ingredients such as green tea extract. A backsheet prevents moisture in the core from exiting the pad and staining clothing. Backsheets may be completely

impermeable or, as it is the case in most modern backsheets, semi-permeable ('breathable'), allowing water vapour but not liquid water to pass. This property contributes to comfort (Schaefer *et al.*, 2002). Research continues to improve both the functional performance of feminine hygiene products and the consumer experience during use.

14.3.2 Skin protection properties of absorbent hygiene products

Skin protection is a particularly important issue in the context of absorbent hygiene products, as the presence of urine, faeces, or menses on skin creates conditions that facilitate the development of irritant dermatitis. This process has been most extensively studied by investigating diaper dermatitis, but many of the basic principles are applicable to the use of other absorbent hygiene products (Runeman, 2008).

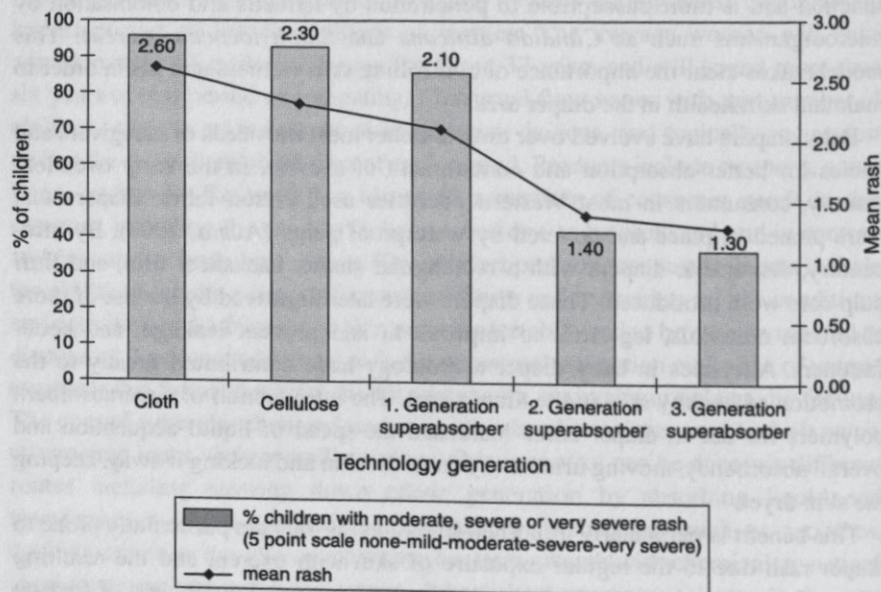
Many factors play a role in the development of diaper dermatitis, including humidity, changes in pH, mechanical friction, chemical challenges, and the skin microorganisms. Berg (1988) proposed a model for the development of diaper dermatitis. In this model, healthy skin of the diaper area becomes compromised following exposure to moisture, mechanical forces, and increased pH (resulting from creation of ammonia from urine via action of ureases from faecal microbes). Wet skin is more prone to frictional damage as a result of its higher coefficient of friction compared with dry skin. The resulting damaged skin has impaired barrier function and is more susceptible to penetration by irritants and colonisation by microorganisms such as *Candida albicans* and *Staphylococcus aureus*. This model makes clear the importance of controlling skin wetness and pH in order to maintain skin health in the diaper area.

Baby diapers have evolved over time to better meet the needs of caregivers and babies for better absorption and containment of excreta. In the early twentieth century, consumers in most Western countries used cotton fabric diapers that were pinned in place and covered by waterproof pants (Adam, 2008). By mid-century, disposable diapers with a rectangular shape, backsheet film, and fluff pulp core were introduced. These diapers were later improved by the use of more absorbent materials, leg cuffs to improve fit and prevent leakage, and better fasteners. Advances in baby diaper technology have contributed greatly to the promotion of healthy skin in the diaper area. The introduction of superabsorbent polymers for use in diaper cores increased the speed of liquid acquisition and overall absorbency, moving urine away from the skin and locking it away, keeping the skin dryer.

This benefit is particularly important in infants, as they are particularly prone to diaper rash due to the regular exposure of skin with excreta and the resulting effects from digestive enzyme (re)activation and increased coefficient of friction of wet skin (Adam, 2008). The benefit of superabsorbent diapers in protecting

babies' skin is illustrated by data showing that the frequency of moderate to severe diaper dermatitis declined by 50% in the period following introduction of diapers using cross-linked sodium polyacrylate polymers ('superabsorber') (Odio and Friedlander, 2000). Further decline of diaper dermatitis was seen with the improvement of superabsorbers from the first to the third technology generation, as shown in Fig. 14.2.

Another innovation that promoted skin health was the development of lotion-impregnated inner topsheets that transfer a petrolatum-based ointment to the skin. A normal stratum corneum prevents the penetration of toxic substances and microorganisms. Damaged stratum corneum allows an increased loss of water (transepidermal water loss; TEWL) and penetration of irritants. Secondly, microorganisms such as *Candida albicans* can colonise those compromised skin areas and contribute to further damage leading to severe rash episodes. Application of barrier preparations (such as the petrolatum-based ointment used in some diaper topsheets) can protect normal skin when the stratum corneum is at risk of damage or can be used in an attempt to improve barrier function in an already compromised stratum corneum and provide protection from wetness (Atherton, 2004). This ointment layer supports skin barrier and protects the skin from excessive hydration and irritants by providing a hydrophobic barrier without occlusion. Studies have shown that ointment-containing diapers provide improved skin protection (Odio *et al.*, 2000a,b; Tate *et al.*, 2007). The presence of the



14.2 Development of diaper rash with different diaper technologies.

ointment on the skin also makes cleaning easier, so fewer irritating contaminants are left on the skin. In a double-blind, randomised trial in children deemed by their parents to be especially susceptible to diaper dermatitis, use of a petrolatum-containing diaper was associated with statistically significant, sustained reduction in the severity of dermatitis compared with a control product (Odio and Friedlander, 2000).

A further development that improves skin health is the use of vapour-permeable ('breathable') membranes rather than impenetrable films for the outer diaper cover. These covers allow movement of water vapour and air, while retaining liquid urine within the diaper. Diapers with these microporous covers have been shown to reduce both the elevated relative humidity and skin hydration found under more occlusive diapers (Grove *et al.*, 1998). Use of breathable diapers reduced the incidence of infection with *Candida albicans* and the prevalence of diaper dermatitis compared with non-breathable diapers (Akin *et al.*, 2001). This technology has also been applied to feminine hygiene products; breathable back sheets in panty liners have been shown to reduce temperature, humidity, pH and the number of microorganisms on the vulvar skin compared with non-breathable liners (Schaefer *et al.*, 2002; Runeman *et al.*, 2003; Runeman *et al.*, 2004).

Adults who use absorbent incontinence products may experience dermatitis as a result of the same basic factors seen in infants who use diapers, but there are some factors that are different. Specifically, the skin of elderly persons is more fragile and subject to injury, with poorer healing than baby skin. Also, urinary incontinence in adults is not always accompanied by faecal incontinence, so effects resulting from the mixing of urine and faeces are not a problem for many adult users. Skin health of elderly under nursing care may be compromised by both incontinence and by pressure sores or moisture lesions, so that it is sometimes difficult to identify the primary cause of a lesion. The incidence of skin problems in institutionalised patients is related to the quality of care, patient mobility, the quality of the incontinence products being used, and the medical, physiological and mental condition of the patient (EDANA, 2008). In general, occlusion and wetness contribute to skin problems in adults with incontinence as they do in babies, so products that are highly absorbent and 'breathable' are likely to be most protective of skin health.

External feminine hygiene products have been tested in many parts of the world under a wide range of conditions and have been found to have no adverse skin effects (EDANA, 2008). Concern that superabsorbent pads might cause drying of the skin and resultant low humidity dermatitis has not been proven to be true. The use of sanitary napkins is limited to days around and during the menstrual period; such intermittent use might be expected to have less impact on skin than products that are used daily and continuously, like baby diapers and adult incontinence products. The use of panty liners for protection between periods is not expected to result in any skin problems, as breathable panty liners with acidic cores produce

skin conditions (i.e., temperature, pH, and microflora) that are very similar to those present when the product is not in use (EDANA, 2008).

14.3.3 Hygiene implications

Disposable superabsorbent hygiene products promote cleanliness by containing bodily fluids and excreta and allowing them to be disposed of in an appropriate way. Faeces contain up to 10^{10} bacteria per gram of weight (Frank *et al.*, 1998; Hoogkamp-Korstanje *et al.*, 1979) and the faecal microbiota in infants is estimated to consist of 20 genera and 100 species (Benno *et al.*, 1984). Several epidemiological studies have shown that diapered infants can contribute significantly to environmental contamination with microorganisms, especially in daycare settings (Campbell *et al.*, 1988; Van *et al.*, 1991a; Van *et al.*, 1991b). Diarrhoea is common in infants and children, and proper hygiene, including safe disposal of faeces, is important in prevention of the spread of diarrhoea (WHO, Huttly *et al.*, 1987). In addition to providing skin protection benefits, disposable superabsorbent diaper products provide better containment of the excreta, reducing environmental spread of pathogenic organisms. This benefit may be of particular value in group settings: a panel of experts has cited reduction of faecal contamination in day care settings as one advantage of using highly absorbent and leak protective diapers (EDANA, 2008). In addition, a randomised trial in a day care setting has shown that significantly fewer objects were contaminated with faecal coliform bacteria in rooms in which children wore disposable superabsorbent diapers compared with double cloth diapers and plastic overpants when no overclothes were worn (Van *et al.*, 1991b). The risk for diarrhoeal illness in day care centres has been clearly linked with contamination of hands and items such as toys (Laborde *et al.*, 1993), so prevention of such contamination is an important step in controlling the spread of illness in this setting.

It should also be noted that, when thrown away in the rubbish, the soiled disposable diaper is typically wrapped tightly using the diaper tapes, providing additional containment of the faeces until safely disposed of by incineration or in a landfill. In contrast, reusable cloth diapers must be retained and laundered, allowing many opportunities for contamination of hands, surfaces, or other aspects of the environment with faecal organisms.

Hygiene issues for adult incontinence products are similar to those for baby diapers. In institutional settings, especially, the ability to confine and dispose of urine and faeces with a minimum of effort and without contamination of the environment is paramount. Use of modern disposable absorbent incontinence products should reduce the amount of time required to clean and care for incontinent elderly or frail patients, the costs and time needed to wash soiled clothing and bedding, and the risk of spreading illness in the institution through contamination. In active adults, use of modern, highly absorbent incontinence

products allows continuation of a normal routine outside the home, without fear of leakage and embarrassment in public.

Studies on the survival and movement of enteric viruses and bacteria in landfills have demonstrated that the microbial population of the leachate decreases with time (Pahren, 1987). Indicator organisms of faecal contamination and enteric viruses are extensively inactivated by the leachate in landfills and viruses do not escape from landfills (Sobsey, 1978; Sobsey *et al.*, 1975). Disposal of baby diapers, adult incontinence products, or feminine hygiene products in proper solid waste landfills has not been associated with any risk of disease to waste collection workers or the public. In contrast, recent research in China has been shown that the use of disposable diapers provides a significant advantage over cloth diapers in the microbial contamination of skin and household surfaces (Adam and Odio, 2009).

14.4 Testing of absorbent hygiene products

14.4.1 Testing of technical properties

As disposable hygiene products have become more complex and their materials more sophisticated, researchers have developed a number of testing methods for use during the product development process. These methods ensure that new products will deliver both the functional performance and the wear experience expected by the consumer. This testing includes measurement of chemical, physical, and absorbent properties of raw materials and test products. Some tests, such as those measuring raw material properties or speed of fluid acquisition, are relatively simple, while others, such as determination of fit during use, may be more complex. A particular challenge in this category is the development of laboratory testing methods that simulate the variety and complexity of actual product use and allow correlation of different physical parameters (flow levels, loading, activities, product shape and fit with anatomy during different activities, etc.). The most important product improvements in disposable hygiene products (e.g. superabsorbent materials, fluid-acquisition topsheets) have come about through in-depth understanding of the physical properties of materials and their interactions with fluids under use conditions, often obtained from returned products after usage by consumers. Detailed and exhaustive laboratory testing makes possible the development of optimal prototype products for progression to human clinical testing.

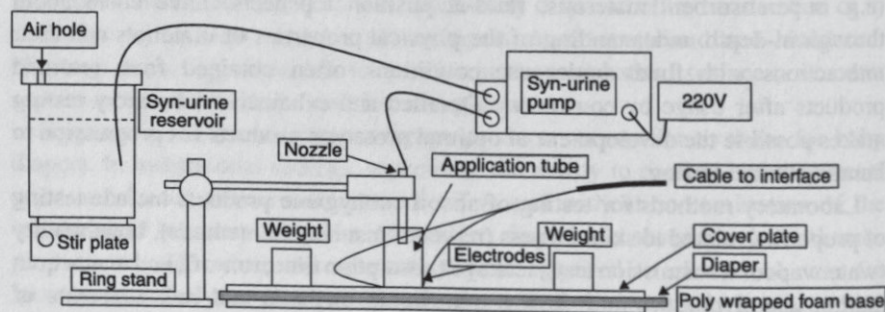
Laboratory methods for testing of absorbent hygiene products include testing of properties related to skin dryness (rewet or mannequin methods), breathability (water vapour transmission test), leakage (absorption time, run-off, and mannequin methods) and product fit (moving mannequin methods and measurements of stretch). A variety of absorption tests have been developed in order to examine different parameters related to fluid handling by the absorbent system (retention,

rewet, released fluid percentage) (Hardy, 2009). Tests of the total absorption capacity (centrifuge retention test, Rothwell test) are applied today for quality assurance testing, but not for comparisons of different products, as modern products can vary a lot in capacity without showing a difference in performance. For light incontinence pads for women, it has even been recommended that the Rothwell test be withdrawn completely (Cottenden *et al.*, 2006). If a lotion is applied to the topsheet of an absorbent hygiene product, methods to measure lotion transfer are also employed, as are measures of the amount of free fluid on skin. Speed of fluid acquisition is also critical in adult incontinence products, as are issues of leakage and fit under conditions simulating actual use. The ability of materials to neutralise odours associated with urine is also important in this category.

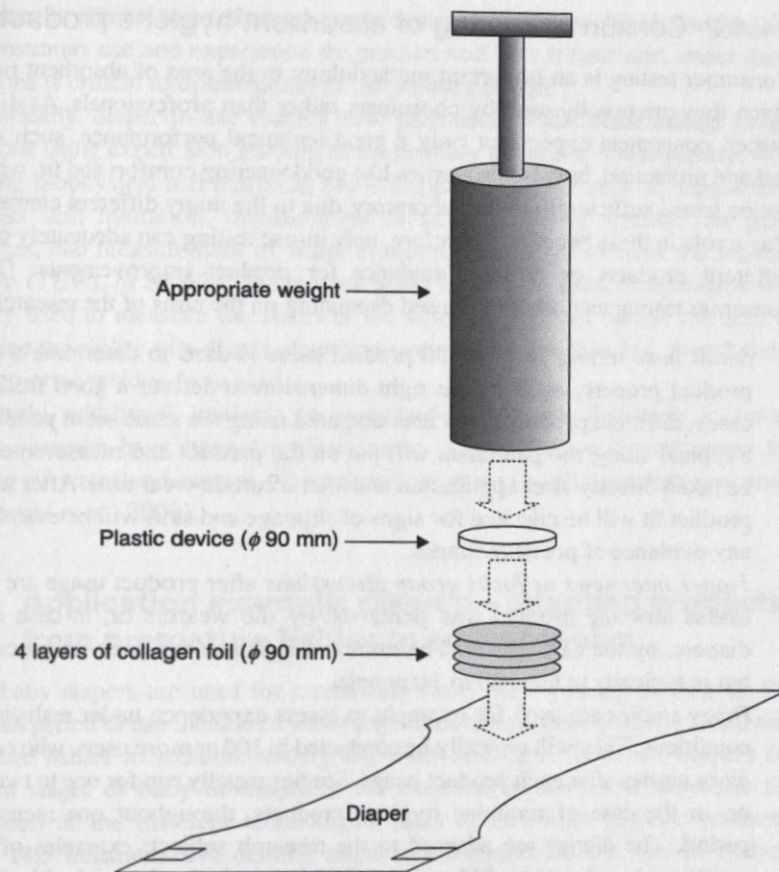
In many cases, laboratory testing of materials may employ substitutes for bodily fluids such as simulated urine (e.g. 0.9% saline solution) or simulated menstrual fluid. These materials are designed to behave like the natural materials but avoid the problems of obtaining and handling biomaterials.

As examples, we describe here the principles of two of the most common methods used to characterise absorbent hygiene products, 'absorption time' and 'rewet'.

Absorption time (Fig. 14.3), i.e. the time needed to absorb a certain amount of fluid, is strongly correlated to the probability of leakage. Figure 14.4 shows a drawing of a typical apparatus used for this measurement: The test product, here a diaper, is laid with the backsheet side onto a polyurethane-foam base and covered with a cover plate, as shown. Weights are placed onto the cover plate to simulate the weight of the baby lying on the diaper. Because of the foam base the pressure is distributed equally across the diaper. The cover plate has a hole which is placed over the area, where the diaper typically absorbs urine. An application tube containing an electrode connected to a computer is mounted over that hole. A certain amount of synthetic urine is pumped into the application tube and with help of the electrode the time is measured until all liquid of the tube is absorbed



14.3 Schematic drawing of a device to measure 'absorption time' of a diaper.



14.4 Schematic drawing of a 'rewet' measurement.

by the diaper. This is repeated three to four times to simulate the repeated urinations of a baby. Results are recorded as absorption rates, i.e. volume per time (ml/s).

Rewet (Fig. 14.4) methods are used to assess the amount of liquid that has been absorbed but is squeezed out again under pressure, e.g. when the wearer sits down. A low rewet is important to keep the wearer's skin dry. Figure 14.4 shows a schematic setup of a rewet method: A diaper is loaded with a certain amount of liquid. After a waiting time (typically 5–10 minutes) an absorbent material is laid on the topsheet in the area, where urine is usually absorbed in real use. The material is weighted before. Often filter paper is used as absorbent material, but modern methods use collagen instead, which has absorbent properties closer to human skin. Then a weight is applied onto the material, simulating the wearer's weight when sitting down. After the weight is removed, the amount of liquid absorbed by the absorbent material is determined by weighing the material again and calculating the difference. Results are reported in weight, either as grams or milligrams.

14.4.2 Consumer testing of absorbent hygiene products

Consumer testing is an important methodology in the area of absorbent products, given they are usually used by consumers rather than professionals. As discussed earlier, consumers expect not only a good technical performance, such as good leakage protection, but also properties like good wearing comfort and fit, which can not be tested sufficiently in the laboratory, due to the many different elements that play a role in these benefits. Therefore, only in-use testing can adequately compare different products or provide guidance for product improvements. Different consumer testing techniques are used depending on the aims of the research:

- *Small base testing* in 10 to 30 product users is used to determine a specific product property such as the right dimension to deliver a good fit. In these cases, different product types are compared using the same set of panellists. In a typical study, the panellists will put on the product and measurements will be taken directly after application and after a certain wear time. After wear, the product fit will be checked for signs of slippage and skin will be examined for any evidence of pressure marks.
- *1-on-1 interviews or focus group discussions* after product usage are used to assess how the product was perceived by the wearers or, in case of baby diapers, by the care givers. The number of consumers interviewed can vary, but is typically at least 20 to 30 people.
- *Diary studies* are used for example to assess experience under realistic in-use conditions. They will typically be conducted in 100 or more users, who complete diary entries after each product usage. Studies usually run for one to two weeks or, in the case of feminine hygiene products, throughout one menstruation period. The diaries are adapted to the research subject; examples of typical questions in a diary would be if a product had leaked, where it had leaked, and how long it was used. Panellists may also be asked to return used products for a laboratory assessment, so that the technical measurements on the used products can be compared with its in-use performance as recorded in the diary.
- *Consumer perception tests* might be used to determine the perception of a product by consumers. They are typically placed in 100 or more consumers, who are provided with enough products to use for one to two weeks. Consumers are asked to fill in a questionnaire after the product usage, in which they are asked about their perception of the product (e.g. 'How do you rate the product quality overall?'). In perception tests, different products might be placed with the same consumer group (paired comparison test) or different sets of consumers (parallel test), depending on the research objective.

14.4.3 Clinical properties and testing

Although well-designed laboratory test methods are critically valuable to the development process, the ultimate testing of any new absorbent hygiene product

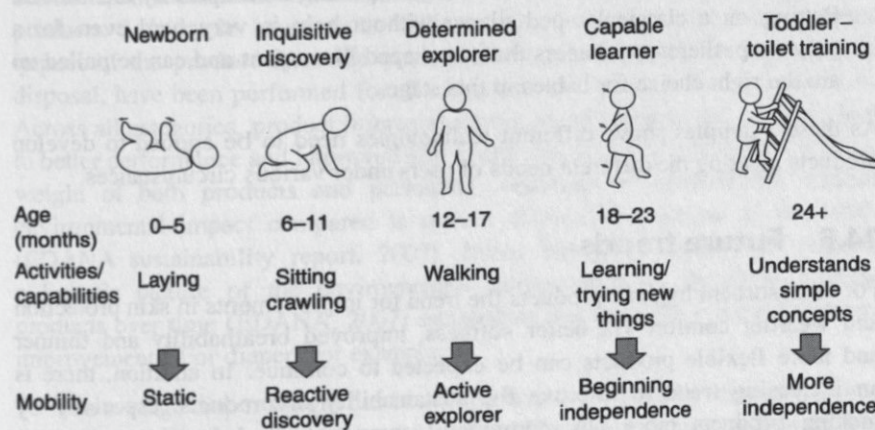
takes place in clinical tests of actual use by typical consumers. Understanding the way consumers use and experience the product and how it functions under these conditions is critical to optimisation of the product design.

Historically, diaper in-use studies were performed under standardised in-use conditions using expert skin grading as the primary endpoint. Subsequently, with emerging biophysical test methods, physiological endpoints such as capacitance to assess skin hydration, measurement of skin pH using specific flat glass electrodes, and measurement of water evaporation through or from the stratum corneum (TEWL or SSWL: skin surface water loss) were used. Evaporation was not only used to measure the status of the stratum corneum barrier but also to determine the ability of a diaper absorbent core to keep the skin dry, absorb fluid, and keep urine residue from skin.

Recently, additional methods to investigate the water dynamics in infant stratum corneum have been described, using *in vivo* Raman Spectroscopy for profiling of water and natural moisturisation factors in infant stratum corneum (Nikolovski *et al.*, 2008).

14.5 Application example: diapers – adapting products from premature babies to toilet training

While baby diapers are used for a relatively short period during the human life span, this period of use includes a wide range of developmental progress, from tiny premature babies to toddlers undergoing toilet training. Therefore, diapers for different stages of baby development are excellent examples to showcase the application of the different technologies used in absorbent hygiene products. Figure 14.5 illustrates five distinct stages of development that can be defined



14.5 Stages of development in a baby.

during the diapering period, each with a different level of physical and mental capabilities.

To further illustrate the effects of these stages on product requirements, the differences between products made for three of these stages are described below:

- *Newborn stage*: In the first three to five months after birth, the parents are especially concerned with protecting their newborn baby's skin and making the transition from the mother's womb into the world as smooth and comfortable as possible. Babies in this phase experience the world especially through feeling and listening, while the visual sense is not yet well developed. Thus, in the diaper context the tactile properties are particularly important. As babies in this phase usually have liquid or soft stool, protection against bowel movement leaks is a particular performance need. Therefore, diapers for newborns are usually made from especially soft materials, and they often feature specific technologies to allow absorbency of soft stool and good leakage protection. As for any stage, absorbency of urine to provide skin dryness and urine leakage protection is important, too.
- In the '*determined explorer*' stage, babies have become able to walk and are very mobile, so it is important that this mobility not be inhibited by the diapers. Therefore, diapers for babies in this stage feature not only good absorbency but also elastic elements such as stretch sides to adapt to the baby's body during movement, and are made especially thin and narrow between the legs for a good and comfortable fit.
- Once babies enter the '*capable learner*' stage, they start to become more independent from the parents and more self conscious. Therefore, they try to do many tasks on their own that parents have previously done for them, such as trying to dress themselves or taking off/putting on diapers by themselves. Putting on a classical taped diaper without help is very hard even for a grown-up; therefore, diapers that are shaped like a pant and can be pulled up are the right choice for babies in this stage.

As these examples show, different technologies need to be applied to develop products meeting the different needs of users under various circumstances.

14.6 Future trends

For all absorbent hygiene products the trend for improvements in skin protection and wearing comfort via better softness, improved breathability and thinner and more flexible products can be expected to continue. In addition, there is an increasing trend to improve the sustainability of products, especially by making products more environmentally compatible and by decreasing the overall impact on the environment throughout the whole life cycle of products.

14.6.1 Technology trends

One key trend is the continuous improvement of the absorbing materials used for absorbent hygiene products, in particular the superabsorbent polymers. Improvements in the chemistry of these absorbers make it possible to have much higher concentrations of them inside the absorbent cores, so the amount of cellulose fibres can be reduced, leading to very thin and flexible yet highly absorbent products.

Another trend is the introduction of new film and nonwoven materials, made possible by new fibre chemistries that provide more softness and breathability at affordable costs, improving the wearing comfort of incontinence products and feminine pads.

In the area of skin care, some manufacturers have started to add cosmetic formulations to the topsheets to provide better skin care. It is likely that this will continue with improved formulations and ingredients.

Finally, technology is being used to improve the environmental profile of the products. New materials provide the same performance with lower weight, creating positive effects throughout the product life cycle by minimising energy use for production and transport and reducing waste. Replacing oil-based materials with materials based on renewable resources is an important trend. While some manufacturers have started to use biodegradable materials, this approach is not without problems, as composting diapers and incontinence products causes concerns because of the high load of faecal microorganisms. These issues will need to be resolved before the full potential of biodegradable materials can be realised.

14.6.2 Sustainability

In a world in which environmental and social responsibility have become serious concerns, all manufacturers need to understand the environmental impact of their products. Life cycle assessments (LCAs), which evaluate the environmental impact of the product from the production of raw materials through to final disposal, have been performed for all categories of absorbent hygiene products. Across all categories, product improvements in recent decades did not only lead to better performance and improved skin health, but also have resulted in reduced weight of both products and packaging, resulting in substantially reduced environmental impact compared to typical disposable products of the 1980s (EDANA sustainability report, 2007). Using the LCA method to generate a holistic picture of the environmental performance of absorbent hygiene products over time (EDANA, 2007) established that there have been significant improvements. For diapers for example:

- The average diaper weight has been significantly reduced by almost 40% in a period of 17 years, from around 65 g in 1987 to 56 g in 1995 and to 41 g in 2005.

- The weight of packaging has been reduced by 41% from 8.0 kg per 1000 pieces in 1987 to 4.7 kg per 1000 pieces in 2005.
- There has been an overall reduction in the environmental impacts of using diapers over the diapering period of one child of 32% between 1987 and 2005.
- The global warming and the summer smog impacts of diapers reduced between 1987 and 2005 by 37% and 43%, respectively.

Similar positive trends have been shown with incontinence products and their packaging. The LCA study has been conducted by the German research institute IFEU (Institut für Energie- und Umweltforschung, Heidelberg) and has been independently peer-reviewed according to the ISO 14040 series standards.

Many consumers are concerned about the relative environmental impacts of reusable cloth diapers and disposable diapers. The impacts of cloth and disposable diapers have been evaluated in numerous LCA studies around the world, with the overall conclusion that neither diaper option is environmentally preferable. In 2005 and 2008, the United Kingdom's Environment Agency assessed three diaper types: disposable, home laundered cloth diapers, and commercially laundered cloth diapers delivered to the home. This LCA study evaluated the potential environmental impacts associated with an average child wearing nappies during the first 2.5 years of life. The environmental impacts indicators assessed included: resource depletion; climate change; ozone depletion; human toxicity; acidification; fresh-water aquatic toxicity; terrestrial toxicity; smog; and eutrophication. The conclusion was that there is no significant difference between the environmental impacts of the three diapering systems; none of the systems studied is more or less environmentally preferable. The environmental impacts of the diapering systems are different, however. Environmental impacts are linked to the energy, water, and detergents needed to clean cloth diapers, and to raw material production for disposable diapers. Consistent with previous industry association LCA studies (EDANA, 2007), the UK study indicated that the potential environmental impacts of disposable diapers could be reduced by decreasing product weight and improvements in materials manufacturing, while the impact of reusable cloth diapers could be minimised by reducing the energy required for washing and drying. In its update in 2008 the LCA study also confirmed improvements for disposable diapers, e.g. 12% less Global Warming Potential and 13.5% less material usage since its first study in 2005 due to manufacturing changes. In terms of Global Warming Potential, the UK Environment Agency showed 550 kg of carbon dioxide equivalents for disposable diapers, while this number was higher for cloth diapers with 570 kg of carbon dioxide equivalents.

Although raw material production is the primary driver of potential environmental impacts for disposable diapers, there is public interest related to used diaper waste. The UK study also found that the impact of waste from the three diapering systems did not contribute substantially to overall municipal solid waste in the UK. The global warming and non-renewable resource depletion

impacts for the 2.5 years in which a child wears diapers are similar to the impact of driving a car for between 2100 and 3500 km (EDANA, 2007).

Waste from absorbent hygiene products accounts for less than 0.5% of total solid waste in the European Union (EDANA, 2007). Used hygiene products are most commonly disposed in sanitary landfills or incinerated with the heat from burning used to generate steam or electricity. In a few areas used products undergo a controlled form of composting, through mechanical-biological pretreatment or anaerobic digestion prior to recover energy or organic materials, and reduce the residue that is incinerated or landfilled. Manufacturers continue to work to identify ways to reduce the environmental burden associated with products throughout their life cycles. This goal may be accomplished by making more efficient use of natural resources and reducing waste, energy use, and carbon dioxide emissions.

14.7 Sources of further information and advice

Helpful, up-to-date information in this area can be found on the webpages of EDANA, the International Association Serving the Nonwovens and Related Industries based in the EU (www.edana.org), the Absorbent Hygiene Products Manufacturers Committee (HAPCO) of EDANA (www.hapco.edana.org), INDA, the Association of Nonwoven Fabrics Industry based in the US (www.inda.org), and similar, smaller associations in several countries.

14.8 Acknowledgements

The authors acknowledge the assistance of Lisa Bosch in the preparation of this chapter, Dr Mattias Schmidt for reviewing, and Annie Weisbrod PhD and Dr Ioannis Hatzopoulos for environmental sustainability and LCA perspective.

14.9 References

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