13

Protection of, or by, textiles from environmental damage

13.1 Aspects

There are three aspects of protective practices that concern textiles. The first is the matter of protecting textile materials from degradation as a result of exposure to environmental hazards. The second concerns the use of textile materials to provide protection for people or objects against environmental hazards. The third involves the provision of protection, in the form of textile components, for the environment against hazards resulting from natural or human causes. All three are important, but differ in their manner of action, and all three need to be considered in this chapter.

We have already seen how a wide range of environmental factors can bring about damage to textiles. Protection against these has to take place at all stages in the existence of the materials, from their initial harvesting to their final use. Storage and maintenance should not be forgotten in the list of stages to be included in any survey of the subject. Care to avoid damage from incorrect moisture balance, excess temperature fluctuations and chemical or microbiological hazards during storage is crucial for many fibre types, but especially for those of natural origin. In moist conditions, as mentioned elsewhere in this book, cotton, wool, silk, linen and various other less frequently used natural materials can suffer damage from exposure to mildew, mould or other microbiological hazards. They (and many synthetic materials) can also be degraded by exposure to ultraviolet radiation. Thus, if a textile product is to be stored for a long period of time (more than a few weeks, for example), it should be wrapped or located in such a manner that humidity cannot come into contact with the fibres. Moisture in the form of liquid water or in the gaseous phase (in very high humidity conditions, for instance) should be excluded completely. The more severe the moisture conditions, the less time should be allowed before storage in waterproof wrapping is achieved, and the more resistant a fibre type is to microbiological or chemical attack, the longer the delay that can be permitted before taking this precaution.

On the other hand, a totally dry storage medium can bring about embrittlement over a period of time, so a reasonable amount of moisture should be present in the air that is in contact with the textiles. Ideally, the conditions should approximate those of standard temperature and moisture content, 21°C and 65% relative humidity, respectively. Under such conditions, storage for a prolonged period can be expected to produce little or no change in the material, as long as light is also excluded. Other harmful chemical agents, of the types summarised in the previous chapter dealing with chemical and microbiological attack, must also be prevented from coming into contact with the goods, or they may suffer damage.

13.2 Maintenance

In the need to maintain materials, there are steps that should be adopted for their protection. Care should be taken to avoid using incorrect reagents for specific fibre types. The obvious example of this is the need to avoid chlorine bleaching agents in connection with wool or silk, or in a dyed fabric that will not tolerate this reagent without loss of colour. High alkalinity in detergents can also bring about destruction of some fibres and decolourisation of certain types of dyestuff over a period of time. Other fibres (notably acetates) are very sensitive to specific solvents, such as acetone and chloroform, and can be destroyed rapidly even on brief contact with these substances. Thermal attack can create difficulties for heat-sensitive fibre types, so precautions need to be taken during drying or ironing of, say, nylon, polyester, olefin or other synthetic fibres.

13.3 Degradation during use

Although the storage and maintenance of textiles can influence to some extent the effect of the environment on their longevity, it is normally the degradation taking place during use that is the crucial consideration when considering protection of fabrics. There are, in general, two distinct methods of achieving such protection, the exclusion of the harmful material and the deflection or neutralisation of its effects. Typical examples of the former technique include coating of the fibres in some way. Waterproof or oil-resistant fibre or fabric coatings, for instance, are used to prevent staining of household goods such as table linens, carpets or furnishing fabrics if contact with a spilt foodstuff or some kind of contaminant (perspiration, hair cream, deodorants, etc.) present on a human body occurs. Fabrics intended for use in sensitive areas, where contact with microbiological agents can occur (in gardening or filtration applications, for example), are often covered with a plastic film or fibre coating to delay rotting. Surface friction can be reduced, where mechanical action is likely to bring about premature wear into holes, by the use of coatings of, say, polytetrafluoroethylene (PTFE) on fibres or cloth to provide low-abrasion contact. Resins may be placed on the surface of fibres to control shrinkage that could make the fabric ineffectual for its particular end use.

13.4 Chemical treatments

Alternatively, a comparable degree of protection can be achieved by using chemical treatments that are absorbed into, or adsorbed onto, the fibres. Water-repellent or oil-resistant finishes can also prevent staining on household fabrics and often have a much less noticeable presence because they are not detected as easily by touch as a plastic coating. This second technique, for this and other reasons, is usually greatly preferred to the coating one, and is by far the more common of the two approaches. It is applicable, too, to other types of protection. Flame-resistant finishes are commonplace nowadays and are compulsory in many jurisdictions for specific end products, such as children’s nightwear, theatrical curtains or set decorative pieces, and wall coverings or upholstery in public buildings. Softening agents, to reduce wear by abrasive contact as well as to make a fabric more comfortable to the touch, are regularly applied to clothing or household materials. The same reagents, usually of the quaternary ammonium class, are also effective against static electricity discharge that can cause shock. Microbiological attack is prevented or drastically reduced by finishes to combat rot, mould or insects such as carpet beetles or moths. Chlorination treatments are used to prevent wool shrinkage which, as mentioned above, can make a fabric unusable.

13.5 Protection of humans

The second part of the topic of protection, that of using textile goods to reduce hazards to human beings, can overlap some aspects of the first one. People prefer to remain dry, for instance, so the means of providing the ability to keep a textile from rotting in water can be modified to keep human beings dry in a rainstorm. Again, coating or chemical finishing methods are both applicable in this aim. People do not like electric shocks or garments that stick to them as a result of static electricity generation or discharge, nor do they like the feel of harsh fabrics in contact with their skin, so the use of quaternary ammonium compounds as softeners to protect fabrics from abrasion may also provide comfort to the wearer of garments made from them by preventing electrical discharges or static cling. The same treatment on carpets or furnishing fabrics can reduce the chances of an accident if a shock causes somebody to drop a glass object or to suffer a heart attack. An anonymous author[1] reviews protective garments, taking into consideration fibre types, safety needs, survival factors, weather-resistant or other specialised applications, health, medical, military and defence uses. Hilden[2] reports a conference dedicated entirely to health, safety, operative protection and environmental technology.

13.5.1 Prehistoric protection

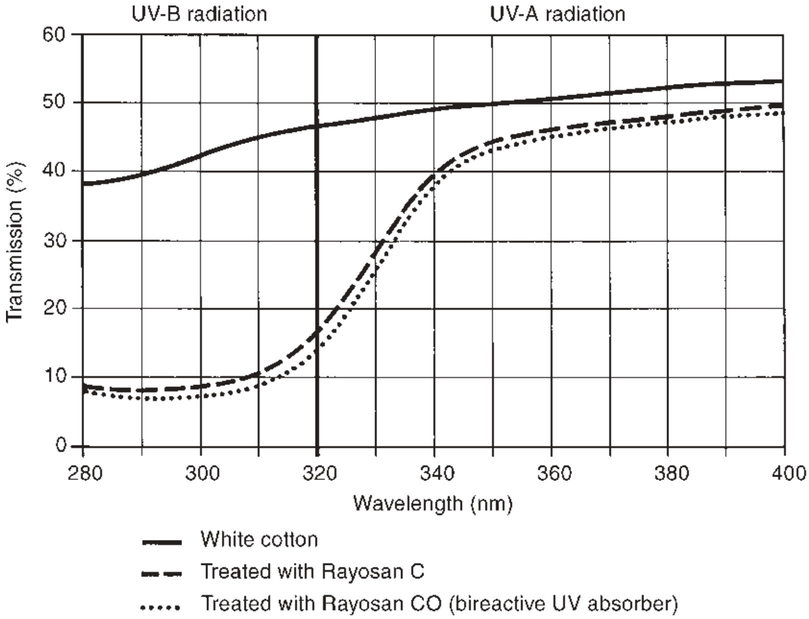
Although the protective nature of specially designed clothing has become of paramount interest, we must not overlook the original uses of textiles by our prehistoric ancestors. These early humans covered themselves to prevent death or injury from the cold climate of ice ages, or from overexposure to the harmful ultraviolet radiation from the sun, once the hairy outer coating of the prehuman creatures had been lost. The coverings also reduced the risk of injury from abrasive contact with stones, trees, hard ground and other such hazards that they must have encountered at least as frequently (and probably even more often, given their roving pedestrian lifestyle) as do their modern descendants. Garments to reduce the effects of weapon thrusts would also be a contributory factor to success in battle, and hence to survival, in those distant days. Subsequently, at a later time in history, uniforms must have played a part in making sure that a friendly warrior did not accidentally wound or kill somebody on the same side as himself in mistake for an enemy. Even today, we continue to seek protection from the natural environment by using clothing to provide thermal insulation in a cold winter, or radiation protection in strong sunlight, or water resistance in a heavy storm.

13.5.2 Ultraviolet protection

Auger and Nantel[3] carry out a general review of the factors associated with ultraviolet exposure, discussing the risks involved with regard to skin cancer and the various types of the disease. Prevention and protective factors, measured with the aid of ultraviolet analysers, are considered in the fabric context. The authors note that construction, the presence of liquid moisture (which reduces protective ability) and colour (dark ones provide better protection than light ones) are all of crucial importance in establishing the overall protective ability of a fabric. Kaspar *et al.*[4] compare the effectiveness of solar protective fabrics in laboratory tests and in use, finding that, for low values of SPF (solar protection factor), the level of practical protection is less than expected from the test results, but that at high SPF values the tests accurately predict field trial results.

An author from Deutsche Telekom[5] and De[6] suggest that ultraviolet radiation should be given more attention as a harmful hazard. De mentions the consequences of excessive exposure, such as sunburn, skin burn damage, ageing and cancer, and emphasises the need for a correct choice of clothing to protect against the harmful rays. He also examines the effects of different fibre structures, weaving patterns, dye shades and finishes, providing definitions of various factors able to express ultraviolet protection properties quantitatively. Similar work is reported by Jedrzejewski *et al.*,[7] who include the effects of construction, porosity, density, raw material composition, bleaching and delustring on ultraviolet absorption. One author[8] carries out a series of tests and recommends that a knitted structure made from a blend of synthetic fibres with Lycra offers the best protection against solar radiation. Percival[9] tests the effects of several factors, including colour and fibre content, but feels that there is a need for more research to take place before definitive conclusions can be drawn.

One writer[10] finds that warp-knitted blinds are able to screen up to 80% of the



13.1 Effect of an ultraviolet-absorbent finish on absorption at different wavelengths (source: ref. 11).

sun's radiation to aid in the preservation of eyesight from bright glare and of thermal comfort in a solar-heated indoor location. Rupp *et al.*[11] present a detailed survey of the topic of solar protection by textiles, noting that special constructions, finishes and ultraviolet-absorbent fibres are all used in this application. Transmission varies with wavelength, fibre type and presence of dyestuffs; Fig. 13.1 indicates how a special finish can block the harmful UVB rays while allowing most of the beneficial UVA rays to pass through the fabric.

An anonymous author[12] reviews the development of ultraviolet-protective fabrics, and notes that three factors may be involved, the fibre type, the finish applied and the method of fabric construction (or any combination of the above). He reports new finishes capable of providing up to 90% reduction in ultraviolet radiation in the critical 400 to 200 nm wavelength region on any fibre type, with no toxicity, irritation or effects on desirable fabric properties such as handle or softness. He also mentions a fabric that can absorb in the infrared region as well as the ultraviolet, so is cooler to wear. Cantrell[13] surveys the problem of increasing solar radiation and notes that fabric advances allow consumers to select from a range of materials for protective coverings or garments. One article[14] points out that the performance of polyester as the best available apparel fibre for solar protection is confirmed by the level of sales of outdoor garments made from it. Algaba and Riva[15] measure the ultraviolet-protective factor of textile fabrics *in vitro* by using a measurement of transmission through a screen (a fabric or chemical) with the aid of a spectrophotometer. Solar protection factor (SPF, defined as the ratio of the time taken for a patch of skin to develop erythema, or reddening, in comparison with and without protection) is corrected for the nature of the solar spectrum in comparison with instrumental characteristics and to compensate for the fact that not all portions of the spectrum are actually harmful. The authors then provide a table showing the expected consequences of various skin types on exposure to a range of ultraviolet index conditions. Djani *et al.*[16] describe a quick and simple method for assessing the solar protection capacity of textiles, based on the use of radiometers to measure the transmittance of specimens in the UVB (280 to 315 nm) and UVA (315 to 400 nm) regions. They present a summary of the comparative abilities of various fabrics as protective agents, ranking their specimens (best to worst) in the order polyester, wool, polyamide, polyester/cotton and cotton. ASTM standards[17] for sun-protective clothing are now under development for consistency in labelling purposes.

13.6 Modern developments

13.6.1 Protective clothing

More modern developments currently provide most interest in the subject of protection of humans from harm as a result of exposure to environmentally dangerous agents. Fung[18] deals with the topic of protective clothing for sports or industrial purposes in some detail and provides specific information on medical and military types of application. He deals with resistance to infection, adverse weather conditions and nuclear, chemical or biological agents. A survey of some of the latest work[19] includes information on combined flame-retardant and ultraviolet-resistant fabrics, finding (as might be expected) that different types of cloth give different levels of protection. The requirements of protective clothing under new European Union regulations are listed in one paper,[20] and Nieves[21] suggests that the evolution of protective clothing may be driven by government regulations as well as by the market; he also feels that heat stress, comfort and barrier isolation are the most critical factors in any type of protection and examines the issue of disposable versus reusable garments. In modern times, chemical warfare must also not be forgotten as a hazard. Indushekar *et al.*[22] give information regarding this topic, testing several fabrics designed to incorporate protection against flame, oil and water in addition. Finishes are suggested[23] as a means of controlling dust mites to relieve asthma, though complete eradication is felt to be impossible. A word of caution is sounded by Kuhn and Paulus,[24] who feel that there is a need for a simple but reliable indicator of the presence of harmful substances (including chemical agents) on textile materials, from fibre to finished fabric state (especially in connection with the eco-labelling scheme) and propose adopting luminescent bacteria for the purpose.

13.6.2 Protective gloves

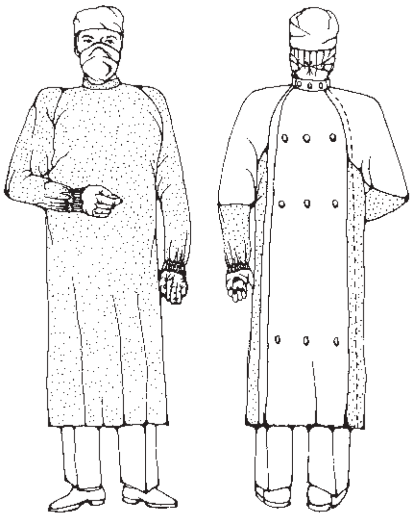
Protective gloves have occupied the attention of various workers. Performance, comfort and wear factors are examined in one case,[25] while another author[26] presents standards for gloves designed against thermal risks of contact, convection or radiant heat and against the small or heavy splashes of molten metal encountered by welders. Bontemps[27] suggests that the use of a core of long-staple fibres wrapped with short staple ones can give a very abrasion-resistant yarn especially suited to protective glove construction.

13.6.3 Surgical gowns

Perhaps the most familiar use of protective clothing is that of the surgical gown which, at least in theory, prevents the surgeon from coming into contact with bacterial infections as he or she carries out surgery (and, incidentally, prevents bacterial transfer in the reverse direction). In practice, traditional surgical operating theatre gowns of cotton are only effective as barrier cloths for a limited period of time (about 20 minutes, according to some experts), although a laminated gown developed by the author some years ago,[28] illustrated in Fig. 13.2, can increase the protective ability considerably. It includes a seamless, water-resistant but breathable front panel, wide under-arm spaces to improve perspiration mobility, knitted structures at collar and cuffs to eliminate abrasion there, and ventilation arrangements, by means of bellows effect airflow, in the rear of the garment. The design provides an additional advantage in that the gown's ability to resist the transfer of liquid water spares surgeons (who often wear a plastic apron over the top of cotton operating theatre gowns) mental worry about their safety, as well as eliminating physical discomfort arising from splashes of blood, irrigation water or other fluids frequently released in operating procedures. With the current notoriety of such diseases as AIDS and Ebola fever, mental comfort is also enhanced by the improved protection offered by such gowns.

13.6.4 Protection against other risks

Protective clothing against other potentially harmful or fatal risks can also be identified easily. Firemen wear suits made from heat-resistant fibres to safeguard them against burns as they fight conflagrations at close quarters. Dirat[29] describes clothing used in the French air force to minimise heat stress and resist exposure to fire or ultraviolet radiation, because he feels that safety and comfort are both closely related to lowered stress levels. Torvi and Hadjisophocleous[30] summarise research into protective clothing for firefighters, with particular reference to the matter of estimating useful life and developing test standards, two areas potentially critical in a fire situation. They also consider the part played by moisture transfer, heat stress, design criteria and chemical protective clothing, recommending future



13.2 A surgical gown with improved effectiveness.

research directions in these topics. Halls[31] summarises the work of the British Textile Technology Group (BTTG) in clothing against heat and flame and the use of sunblinds against both of these is also explored.[32]

Police officers don bullet-proof vests made from Kevlar or other energy-absorbing fibres when there is any risk of being shot. Spider silk is being recommended[33] for use in antiballistic garments because of its high energy absorption capabilities, four times as great as the strongest synthetic fibre currently available. ISO safety standards[34] are published for protective clothing against stabs by hand knives, listing requirements for design, penetration resistance, ergonomic, water permeability and maintenance factors. Another paper[35] gives more details regarding protection against ballistic impact, including information on resistance to bomb fragments using a polyethylene cloth that can also be adapted for armouring cars or heavy-duty marine uses and is stronger than steel or aramid. Thomas[36] provides information of a practical application of this type, and Bell[37] describes garments that protect against knives, guns and hypodermic needles for use by police officers, while Squire and Gaspar[38] provide details of current military protective clothing designed for environmental as well as attack hazards, including aspects that still need attention to enhance protection.

Machinists put on tough overalls to protect themselves against flying pieces of metal, as discussed by Slater,[39] while tree trimming experts use similar materials to cover their legs in case a chain saw slips. In a nuclear power station, operatives working close to the reactors are covered in impermeable layers of cloth or plastic so that radiation leaks cannot reach their skins. Agricultural workers clothe themselves in garments[40] made from fabrics impervious to the toxic chemicals they frequently spray onto their crops; in all of these applications, moisture vapour escape to maintain comfort and heat balance is essential. Ko *et al.*[41] describe the development of a textile that can detoxify pesticides on the surface of agricultural clothing but is still breathable and biodegradable. Detoxification is achieved by means of new functional polymeric materials and these authors examine their effectiveness and the durability of their activity. In a test experiment, methonyl and aldicarb are neutralised by a halamine grafted onto a polyester/cotton fabric and the ability to function is still present after 50 machine washings. In a paper designed to illustrate the extent of skin absorbent poisoning risks, Klasmeier *et al.*[42] investigate the transfer of toxic agents from textiles to the skin. Clarke[43] discusses trends in health and environmental regulations, stating that we need to reduce our exposure to dyes by (for example) enforcement of legislation, risk assessment, black listing defaulting companies, better use of ecolabelling and the banning of skin-sensitive dyes.

13.6.5 Space exploration

Space exploration demands complete isolation from the environment to allow the astronaut to leave the protection of the spaceship and carry out a walk in the total void of space. Employees likely to be exposed to dangerous chemical or micro-biological agents, in a laboratory or production plant, use protective clothing to prevent harm from coming to them. The advent of biological warfare has brought this kind of need to the forefront of our consciousness. Even the simple use of fabrics to prevent sunburn, discussed already, should not be forgotten in this category. Telephone repair staff are provided with garments and equipment designed to protect them against environmental hazards (such as foul weather) as well as against injury,

13.7 Non-clothing protective needs

Protection of human beings in industrial or other non-domestic situations by textile articles that are not clothing should also be considered. Filtration of solids or liquids is an essential part of some processes and may be the deciding factor in establishing whether specific premises can be occupied by humans. In a factory, removal of dust (a problem discussed in detail in Section 5.15.2 of Chapter 5) from the air by filtration allows people to breathe more comfortably and can prevent or lower the risk of lung diseases. Contamination of spaces or samples, in a testing facility or a surgical operating theatre, for instance, can occur if bacteria or impurities that can harm people or invalidate test results are recirculated in the ventilation system. Such an occurrence could produce the impression that danger levels might be greater than they actually are, so leading to an erroneous report on safety, and so on. Filter fabrics again reduce the possibility of this type of problem arising. Food processing plants depend on clean air to eliminate the chances of toxic or otherwise unpleasant products being packaged with foodstuffs, and efficient filtration is necessary to achieve this. In some cases, readings of important data can be distorted merely by the presence of dust in the atmosphere; examples include the detection of smoke particles in a simulated fire situation or the measurement of radioactive tracer detectors in medical equipment testing. Any motor operating in a dusty atmosphere needs to be fitted with a filter to eliminate the risk of fire from overheating by preventing the dust from causing damage to the motor.

13.7.1 Filtration

Liquid filtration that is essential includes an application as simple as the oil in a vehicle. If microscopic particles of metal produced from wear on the engine are allowed to build up and circulate through the lubrication system, the car will quickly seize up and major repairs will be needed. A textile product (or, more commonly in modern vehicles, paper functioning as a kind of textile material) prevents this from happening by filtering out the impurities and allows the car to be driven for an appreciable length of time before the filter has to be replaced to avoid trouble. In food processing, filtration of liquid components to remove foreign particles that could be harmful is frequently carried out in, for instance, the dairy or soft drink industries. Water purification plants can be fitted with polymeric materials to act as primary filters or as a part of osmotic, transfer, barrier or exchange filter mechanisms.

13.7.2 Acoustic protection

Another type of protection offered to humans is an acoustic one where textile barriers are used to reduce the sound pressure level to which people are exposed. Sound energy travels through space in the form of waves and this energy can be dissipated if the waves meet an impedance that is sufficiently resistant to their progress. Textiles are ideally suited to this purpose, because they contain many millions of tiny air pockets that can accept sound waves and allow the energy they contain to be reduced by contact with, and transfer to, the fibres enclosing them. The fibres, having such a small mass, are set into oscillation very easily. The energy of the acoustic wave is dissipated as it is used in forcing this movement to take place, thus reducing the amount that is transmitted through the fabric. Acoustic barriers of this type are used in such diverse places as inside the engine compartment of a vehicle, in buildings such as libraries, factories or churches, and in aircraft passenger cabins. There are two distinct modes of operation, one in which the barrier prevents sound from passing through to an adjacent location, the other in which the energy present within a specific room is reduced within that space, and the nature of the absorbent differs in the two cases. In the former one, heavy, thick fabrics with solid surfaces are more effective, while a loose fabric with plenty of air pockets (obtained when long, loosely twisted yarns are closely packed together) is preferred for the latter situation.

13.8 Protection for the environment

13.8.1 Landfill liners

The final section of this chapter, perhaps the most interesting but least familiar in modern times, is the use of textiles to provide protection for the environment itself, a kind of 'debt repayment' for all the damage done during manufacture of fabrics. One of the current uses of this type of protection is that of a landfill liner. This device is of benefit both to the environment and to humans, because it prevents the leaching out of toxic substances, so that they do not contaminate the ground water, and also ensures that human beings are not poisoned by them. Desirable properties for such a barrier include long life, resistance to mechanical action or ultraviolet degradation and attack by chemical substances (especially corrosive agents or solvents) that might be present with the materials dumped on the waste site. In general, geotextiles are used for this purpose. The fabric will probably be some kind of plastic, although coated traditional textile materials are sometimes used. The vital property needed is extremely low liquid permeability which can best be achieved by using these types of construction. Two anonymous authors review the advantages and applications of geotextiles for a range of uses,[44,45] while another paper[46] recommends them for capping landfill sites because they save money and are easy to install. Andrews and Richardson[47] discuss the design and construction of geosynthetic-reinforced lagoon caps, while Haegemann and Van Impe[48] test the effectiveness of these materials in drainage systems. Reddy and Saichek[49] evaluate the performance of a range of types by testing them in different soils and under different pressures, checking visual appearance, tensile strength and moisture vapour transmission, and find that (as can logically be expected, since surface area and hence abrasive contacts will increase) their protective ability decreases as particle size is reduced. Sawicki[50] develops a model to predict the mechanical behaviour of a material embedded in soil, using it to explain changes in the geotextile material. Those used as clay liners may eventually fail, either in use (as mentioned by Stark *et al.*[51]) or even during installation.[52]

13.8.2 Soil stabilisation

Another simple geotextile use is in soil stabilisation, when a fabric is laid on sloping ground to provide a foundation that retains soil in place, instead of allowing erosion to wash it away, until root structures can develop and provide a better, natural, more stable anchoring medium for the prevention of soil loss. For this application, one writer[53] suggests that efforts should be made to commercialise the use of jute but, for long-term applications, this could be a mistake as resistance to microbiological action is essential and jute is not well preserved under moist conditions unless a protective (and toxic) agent is applied to it. The material should also be unaffected by ultraviolet radiation (since it may well be exposed to light in some places), and jute is again not satisfactory in this regard. It does, though, possess the useful attribute of having high liquid permeability, necessary to allow natural water flow to take place so that plant waterlogging does not occur. Terkelsen[54] feels that there is a need to market the entire idea of geotextile use more widely, not only to civil engineers but also to contractors and their ultimate clients. Sutherland[55] reviews the available information on this subject, while Hoga and Zeinert[56] discuss factors involved, as do Di Pietro and Crampton.[57] Fagan[58] tests different types for their effectiveness in improving the protection factor, and other workers[59] compare the properties of various different polymers. Ogbobe *et al.*[60] present two biodegradable materials (little-known natural fibres, malvaceae and pendulucata) and study their effectiveness in comparison with polypropylene, finding them inferior but still acceptable. Again, failure can occur; Palmeira *et al.*[61] carry out a simple analysis to predict how it might happen, while Helwany and Shih[62] develop a test to measure creep and stress relaxation simultaneously, a procedure they regard as essential to a complete understanding of the behaviour patterns. Garg[63] adapts the principle in using a geotextile as a reinforcement for earth in a retaining wall, and Sawicki[64] carries out a creep analysis of such a situation. Lawson[65] explains the criteria for all such uses, with a consideration of causes of success and failure.

13.8.3 Road reinforcement

The same kind of material can also find applications in road construction. Gowtharaman[66] discusses the wide range of uses of this type, including ports, dams, canals, reservoirs and irrigation channels as well as road reinforcement. Mandel[67] provides an extensive list of a similar nature, adding to it railway construction and sea cliff or beach erosion control as well as the uses already mentioned. Botto[68] feels that a geotextile repair for a road surface is far quicker than the traditional one, enabling the resumption of motorway traffic to take place much earlier. One geotextile with low stiffness and another with high stiffness, in combination, are recommended[69] as an optimum way of absorbing stresses imposed by traffic. Another work[70] reports experiences of geotextile use at the subgrade–subbase boundary of a road. Heying[71] suggests geotextiles as a means of reinforcing historic brick streets to extend their life. Mandel[72] proposes them as protection for waterproof sheeting in rapid tunnel construction. High-altitude testing (in connection with Andean mining operations,[73] but useful in predicting road wear) indicates that they behave satisfactorily even under intense ultraviolet exposure, and exhibit good chemical resistance under these conditions too.

13.8.4 Geotextile filters

Geotextiles are also used as filters to permit leaching of drainage water to occur, without movement of soils. Mlynarek[74] investigates the conditions under which successful operation can take place and presents guidelines to enable engineers to carry out satisfactory installation. McKeown and Nelson[75] recommend a similar installation procedure, while Lawson[76] discusses the best way to prevent damage during the process. Richardson and Johnson[77] suggest the use of secondary geotextile cushions to protect the primary fabric from installation damage. Watson and John[78] design a geotextile filter by simulating soil particle bridges on the surface of the material, while Lafleur[79] tests seven non-woven needle-punched geotextiles with ten soils to develop new criteria for selection of an optimum material in specific circumstances.

13.8.5 Water control

Another use which is rapidly becoming recognised is for water control as, for instance, in tidal barrages (floating cylinders, composed of a fabric casing filled with buoyant material, such as a plastic foam) that restrict the intensity of wave action as heavy tides approach a shore. They are effective in preventing shorelines from being washed away by tidal erosion, so protecting the land from gradual disappearance below the sea. Their most famous application is probably their use, to good purpose, in the attempt to preserve the wooden foundations on which the ancient houses of Venice were originally built and which are now disintegrating as a result of modern water pollution. They are also used in various harbours around the world, either for a similar purpose or to provide safe mooring conditions for vessels inside the harbour when storms are raging in the sea itself. Apart from the protection afforded to such vessels, the calming action avoids the need to clean up a polluted shore after a storm has strewn wreckage on the coastal fringes.

Floating textile barriers can be used in the clean-up process necessitated by the all-too-frequent oil spills that have become a familiar problem in the modern industrial world. The mode of action of these barriers is two-fold; they may be used to restrict the movement of oil away from a limited area of containment or they may provide an absorbent sink that soaks up the oil preventing it from leaking away to pollute the surrounding waters more widely. Again, two distinct types of construction are preferred in these two respective cases. The containment feature will be achieved most effectively by using a tight, oil-proof and impermeable material, while the absorbent mode needs an open structure that readily allows oil to penetrate within it, thus easily reaching the internal fibres that can then soak it up.

Storage and containment of other materials may be considered in this section. Steacy[80] provides management with information on how polyethylene liners should be installed, while Skelly[81] uses a geotextile for storage and containment of tannery waste to prevent any failure, in order to comply with environmental regulations. Another author[82] gives details of PVC geotextile cores used for eight sedimentation tanks to withstand erosion from the methane and other toxic gases enclosed by them, noting that they also resist weathering satisfactorily. Control of the banks of a river, canal or other waterway can be achieved in a similar manner. Moran[83] describes the way in which a river is returned to its original watercourse by the installation of a woven coir matting and how the vegetative cover is revived over a period of time. Elias[84] uses geotextiles to reinforce the soil in building a port container terminal and Duensing[85] proposes them as liners for decorative water features.

13.9 Desirable properties

13.9.1 Incorporation

The ways in which the desirable properties can be incorporated into textile materials for all the various needs described in this chapter may be classified simply into three modes. The first of these is the actual manufacturing conditions by which the textile goods are made. Permeability to air, moisture (vapour and liquid) and heat is enhanced by open, looser structures, while impermeability is increased by tight twist, close spacing of yarns, thick layers and polymeric coatings. Strength (and hence resistance to destruction by mechanical action) is achieved by using stronger fibre types, higher twist, thicker yarns and tighter weaving. Resistance to water or other liquids is enhanced by using hydrophobic fibres, tight twist, close spacing of yarns, a plastic or a surface coating. Resistance to ultraviolet radiation, microbiological agents, staining or flammability can be achieved by using finishing treatments.

13.9.2 Manufacturing criteria

Second, the matching of manufacturing conditions to actual modes of end-use operation is a crucial factor in improving the effectiveness of a textile product. If the conditions of use can be predicted accurately, then precautions can be taken to ensure that the necessary treatment to counteract these conditions can be built into the fabrics initially. Strunga[86] stresses the importance of selecting criteria carefully for every geotextile application.

13.9.3 Maintenance

Finally, the maintenance procedures needed to keep the textile product operating at its optimum level should be followed carefully. In the simplest instance, laundering or dry cleaning recommendations should be followed, storage to avoid attack by, for example, moths, should be arranged, and care should be taken not to expose the fabric to sharp objects or harmful materials that can reduce its effectiveness in, say, protection against a dangerous gas or liquid. If these obvious precautions are observed, there is no inherent reason why the material should not continue to give satisfactory service throughout its designated lifespan.

One clear drawback in this otherwise ideal situation is that there are dilemmas to be faced in the choice of conditions, either of manufacture or of use, since the needs of one set of desirable attributes may be diametrically opposed to those of another. If, for example, an impermeable and waterproof fabric is needed for a protective garment, then the way in which it is made will not allow it to be thermally comfortable. The person wearing it may well be protected from the harmful agent to which he or she is exposed, but will be so hot from perspiration that he or she will not be able to function effectively while it is being worn. In the same way, a fabric intended for use as an acoustic absorbent, made from loosely twisted fibres and an open structure, will tend to be weak, and so may not be able to withstand the stresses placed on it when it is mounted in position under tension, or is blown about in a windy setting. A finish intended to impart flame resistance may not be compatible with one that renders the fabric stain or ultraviolet resistant, so a curtain may not be able to resist fire and staining at the same time.

There are many of these potentially incompatible situations. All that can be done is to accept the need to compromise, selecting the optimum set of conditions to achieve the most critical criteria without ignoring completely the ones of lower importance. In this way, the protection needed or imparted by a textile material can be optimised to ensure the maximum possible lifespan for effective operation.

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14
Conclusions

The problem of environmental stress exists and will not go away by magic. The planet is seriously overloaded by human activities, partly because of overpopulation but mainly because a minor fraction of the population that occupies the earth (concentrated in the developed regions of the world) is consuming at a rate far in excess of what the planet can sustain. The sources of stress are of two types, depletion of resources and pollution. Critical resources include the air, water and land, plus minerals contained within the land. Pollution takes many forms, but can be classed (in terms of effects on human beings) essentially into five distinct types, pollution of the air, the water, the land and the visual environment, together with an auditory onslaught.

In general, all human activities, even the act of breathing, are environmentally harmful. Breathing uses up oxygen and releases carbon dioxide, a greenhouse gas, into the air. With some six billion people involved at the time of writing, the amount of oxygen used and of carbon dioxide generated by the population is not inconsiderable. Beyond the simple act of existing at a rest state, everything we do results in resource depletion or pollution of some kind, more severe in its effect than mere breathing, so the net effect of our presence on the planet is a major one. All of our actions are harmful in some way, but most of the adverse changes result from industrial activity. Since the time of the Industrial Revolution, we have steadily and consistently increased our onslaught on ecological stability to the point that we have now reached a situation where, according to many experts, we are overloading the planet by a factor of four to six times its ability, by its inherent compensatory mechanisms, to recover from the damage. All industries contribute to the problem, but the textile sector is often allocated a high share of the blame.

This accusation is unfair, first because the proportion of goods and equipment manufactured or used in textile production is less than 2% of the world's total production figure, making it unreasonable to regard the environmental harm done by the industry as greater than this proportion. More importantly, the products of the textile industry are essential to human survival, unlike those of the vast majority of other industrial output, with the exception of food and housing. Our luxury goods are just that, luxuries. They do not enhance human survival prospects in the slightest and may, indeed, be sources of envy that can bring about harm to humans when they become the motive for increases in crime or terrorist attacks on Western nations thought (with good reason) to be consuming more than their fair share of the world's resources. A country without textiles, though, leaves its population at the mercy of the elements and would need to depend heavily on trade to rectify this drawback. That country would therefore be susceptible to economic or inimical blackmail in times of scarcity or war. Hence, textile production tends to be ubiquitous, so the perception that it causes high pollution problems is shared by most of the Earth's people, a fact that accounts for the high proportion of blame attached to the industry in allocating shares of the world's environmental difficulties. Finally, the products of the textile industry are often used in combating the polluting activities of other industries, providing a valuable aid in the struggle to reduce ecological damage. Textile production should be also credited with this compensatory benefit.

All of this does not mean to imply, though, that the textile industry is blameless in the matter of environmental harm. There are many cases where harmful activities are still taking place, although it has to be said that textile producers are frequently willing to try to reduce the load their actions have on planetary welfare. Damage can arise during fibre production, whether by the agricultural problems associated with the use of fertilisers, herbicides and insecticides, or by the extraction and conversion of oil for synthetic fibre manufacture, or by the heavy equipment needed in mining from the earth minerals used for raw inorganic fibre materials or for making manufacturing equipment.

In yarn production, environmental effects include those caused by the chemicals used in washing, scouring, bleaching or carbonising, together with the emission of gases from drying apparatus or of fibrous fly from baling, opening and carding operations. To them must be added the residues of chemicals used to alleviate spinning difficulties and the presence of dust or noise in the later yarn production steps. Similar adverse results are found in fabric production, where chemical assists, fibre waste and noise are also evident.

It is in the next stage of production, the fabric treatment processess, that most of the well-known polluting actions begin to be most noticeable. This is especially true of dyeing and printing, mainly because the evidence of the presence of pollution is highly visible in a waste water stream. The discarded products of colouration are, indeed, notoriously harmful, because of their toxic or carcinogenic nature. There are, however, many harmful emissions from such processes as shrink-proofing and bleaching, or finishes used to impart desirable properties (such as flame-resistant, water-resistant or easy-care ones) to fabrics. Since the effluent is not coloured by the waste products of these production operations, they often tend to be regarded as less important in the public mind.

When textiles are used, their adverse effects are still to be discerned. Use may be normal or unusual, but will always have some influence on environmental conditions, whether favourable or adverse. One of the most prevalent, but least recognised, harmful effects lies in the premature discarding of fabrics, whether because they have failed before their anticipated date of doing so or because they no longer satisfy the requirements of their purchaser. Discarding for the latter reason may, for clothing, be at the whim of fashion, or as a result of growth that means a garment will no longer fit. In other cases, redecoration may produce a clash of colour in a carpet or furnishing fabric, or an appearance of shoddiness in an older article that is unacceptable. In technical or medical textiles, discard may be the result of inability to fulfil the original function, whether this involves a defect in a protective garment (such as a surgical gown or clothing intended to protect against thermal, space, chemical or biological hazards) or an article, such as a conveyor belt or tyre cord, that needs to have a flawless textile component to prevent mishap or mechanical failure.

The storage and maintenance of textile products are also sources of ecological harm. Laundering and dry cleaning make use of undesirable chemicals, while storage in unsuitable conditions again leads to premature discard because an unacceptable product results. Thus, right from the earliest stages of production to the end of its useful life, a textile entity, whether of fibre, yarn, fabric or end product, is responsible for causing a range of ecologically harmful situations.

Fortunately, the industry has begun to recognise this fact and has started to take steps to rectify the defects. There is a new spirit of commitment in evidence, although this is only especially recognisable at present in the developed regions of the world. Legislation is slowly being enacted to reduce the damage done by the industry (as well as by other industries) to a lower level. Unfortunately, this legislation is not yet satisfactory. It does not place severe enough restrictions on producers to reduce the damage to the point where it can be eliminated by natural processes, it does not apply penalties that provide a real deterrent and it is not enacted in situations where economic harm may result. Since economic harm is an inevitable result of ecological protection if we are to achieve a totally healthy planet, it is difficult to see how a rational and sane society can use this excuse to delay or prevent remedial legislation from coming into force. Even relatively minimal suggestions, like the Kyoto Accord, are not accepted by many people. The fact that these people are still in positions of power and authority is a sad commentary on our unwillingness to accept a lowering of our lifestyle for the sake of the planet's survival.

The author is firmly convinced that the textile industry is capable of meeting any challenge, environmental or otherwise, if given the impetus to do so. This capability has been demonstrated time and time again in the past; the only reason for any reluctance to introduce sweeping changes for the sake of the environment in the present or future is the need to meet competition. Any change takes money and it is unreasonable to expect any company to undertake a major reshuffling of production lines if the result will be bankruptcy because other companies are not undertaking the same changes. Only when legislation forces the changes to be taken by everybody does a fair situation exist; profits are then not squandered because of being undercut by a company reluctant to be environmentally responsible. Also, as long as transportation costs remain at their current relatively low level, the legislation would have to be international in scope so that imports cannot be used unfairly in cheap competition against an ecologically responsible company.

Despite all these problems, the textile industry is still managing to reduce planetary stress brought about by production and use factors. Reduction of harmful emissions into air or water, elimination of highly toxic substances, recycling and attention to problems of noise, radiation and similar consequences of industrial activity, are all taking place. Management staff have gradually become aware that, far from costing them money, environmental protection by these and other steps can actually reduce losses, thus being financially as well as ecologically beneficial. Work has also been carried out to ensure that the harm done by textile goods is lowered. Chemical treatments ensure that the products last longer, give better satisfaction or service and can withstand severe conditions more extensively. The ability to provide protection for human beings exposed to unpleasant or dangerous conditions of climate, chemical, radiative or other harmful exposure should also not be forgotten. Textile goods are used to provide safe conditions of work in industrial or medical applications, as well as to replace body parts that are worn out, so that a human being can survive life-threatening situations.

In addition, textile products have proved to be invaluable in protecting the planet itself against the polluting results of other industrial processes. Geotextiles are used to stabilise soils after vegetation has been removed by clear-cutting forests or overcultivation of agricultural sites. They find applications in isolating harmful chemicals to stop any leaching into water supplies. They control water courses, such as rivers or streams, and prevent erosion of shores along river, ocean or harbour sites. They prevent collapse of roads in times of heavy water flow.

In the future, the industry can probably expect radical changes to be introduced, simply because the planetary load cannot continue to be so devastating if we wish to survive as a species. In order to exist as a viable part of society, textile production will have to be limited, with a lesser choice of products, especially of the kind that are particularly harmful to the environment. This will inevitably lead to an increase in price, because a manufacturer's successful ability to produce goods compels him to use heavy, complex machinery, with high ecological costs, to manipulate the minute units from which all textiles are composed. If the machinery is used less, to cut down on environmental damage, the initial cost will have to be amortised over a smaller number of products, forcing an increase in price of the fewer ones that are produced.

The direction to be taken by the industry, then, is one on which it has already embarked to some extent, although changes will need to be brought about at a much greater rate than is the case at present. The reduction of pollution will play a crucial role in planning operations and factories. This will necessitate cleaner processes, better maintenance and more attention to detail, together with more careful design of equipment, processes and conditions. Less desirable products, with fewer convenience features, may well result, and colour or ease of care selections may be more limited as a consequence. Social standards will be the controlling factor in determining how far we are prepared to abandon our hedonism for the sake of planetary welfare. Government leadership is essential if the industry is expected to convert its operations to more responsible styles.

The textile industry, which led the Industrial Revolution, is perfectly capable of leading the ecological revolution, given a fair opportunity to do so. It can and will become much more environmentally responsible if government leadership allows it to survive while doing so. It is our choice whether we want to make personal sacrifices or to sacrifice our planet instead.