19

Textiles and the environment

Keith Slater

School of Engineering, University of Guelph, Guelph, Ontario NIG 2WI, Canada

19.1 Introduction

The existence of human beings on earth is the result of a fortuitous set of circumstances in which conditions for development of the species were present so that evolution could take place allowing us to reach our present state of being. Our tenuous continuation could be jeopardized at any time by changes in these conditions, and this far-reaching effect could result from shifts which might be totally insignificant by cosmic standards. They could bring about, for example, our inability to breathe, or stay warm or cool enough, or grow the food we need. Thus, we are only able to survive because our planet provides all the sustenance we need without major effort on our part. We can broadly define this set of conditions to which we are exposed as our environment.

One of the minor ways by which we reduce the risk of premature extinction is to guard our bodies from excessive temperature fluctuation by the use of textiles. Textiles are also used to make life more comfortable or convenient for us. Without them, we would find life harsher, and probably not survive with the same life expectancy as we do now. Specifically, technical textiles can provide direct protection in the form of architectural structures, tentage or sleeping bags to provide protection against a cold climate, and geotextiles to guard against swamping by rough water in a harbour or against the escape of harmful chemicals from confinement.

The interaction between textile materials and the environment is a complex one taking two distinct forms. There is, first, the effect of a change in properties that the environment can bring about in the textile, generally classed as degradation. Second, there is the manner in which the production or use of textiles can impinge on the environment, generally classed under the term' pollution for the negative impact', but also including environmental protection by pollution reduction where, say, a landfill liner is used to prevent leaching. A further need is for the production of textiles to be possible by using the resources available on the earth without depleting them irreplaceably. Each of these factors is important and should be considered separately in order to build up a complete view of how textiles and the environment can impinge on one another.

Because this text is intended to be aimed primarily at the area of technical textiles, it is important to consider, at the outset, where such materials fit into the environmental field. If technical textiles are defined broadly as all those not intended for personal clothing or household use, then such end-uses as industrial, automotive, sporting, or architectural ones must be included, as also must geotextiles, tarpaulins, ropes and reinforcement fibres for composites. With such a diversity of products, it is impossible to be specific about fibre content, because all fibres are applicable to one or more members of this range and it is important to take a widely inclusive view in a consideration of the environmental effects of textile production or use.

19.2 Degradation

19.2.1 General factors

Textile materials are exposed to a wide variety of environmental factors during manufacture and use, many of them caused by the very conditions necessary for a proper development of the final textile product. The successful growth of crops, such as wool or cotton, is dependent to a considerable extent on environmental factors. If the temperature is too warm crops can die, so that cotton plants are unable to blossom and sheep cannot be fed. Too much rain can result in plants rotting or in floods that carry away the sheep, again lowering the yield of fibres. The retting of flax or other bast fibres is controlled by environmental conditions, while the presence of too high a relative humidity during storage of some types of fibre, particularly cellulosic ones, can cause damaging mould to develop, rendering them unusable.

In the processing of fibres, artificially developed environments may need to be established. Acid conditions are often essential for various scouring, carbonizing, bleaching, dyeing, printing and finishing operations. Alkaline conditions may be needed, conversely, for mercerizing and other bleaching or dyeing treatments. Heat is needed in some of these processes too, as well as in solvent spinning, drying or tentering. Chemical reagents must be used in sizing or desizing, in some dyeing or printing methods, and in applying finishes such as soil release, antistatic, durable press, flame-retardant, optical modification and shrinkproofing treatments. Moisture and mechanical force are needed in washing, fulling, crabbing, and decating, while dry force is used in beetling, raising and shearing. There may also be specific needs involved with the production of technical textiles, especially if unfamiliar fibres or finishes are to be incorporated.

In this chapter, discussion will be restricted to the changes brought about by exposure of the end-product, as put into service, to expected environmental factors. The effects of any artificially imposed environments present in maintenance of the textile products after they have been put into service are omitted, such as high mechanical force, unnaturally high or low temperatures, chemical agents or organic solvents. These types of stress are important issues for the durability of the textile materials, but word limitation and the nature of the chapter's content do not allow either space or reason for their inclusion.

19.2.2 The degradative process

Degradation may thus be manifested as either a visual effect, which is merely unsightly, or as a physical one in which the material disintegrates in some way under a load. In either case, the net result is that the end-product becomes unacceptable to the consumer for useful service. In the case of technical textiles, there may also be a risk of danger if, say, a sling or rope breaks, an architectural flexible structure or a fibre-reinforced composite structural element collapses, or a landfill liner or tarpaulin bursts.

19.2.3 Importance of degradation

The degradation of textiles in use is universal and inevitable. As soon as the product is put into service, it is subjected to the action of all the agents that can bring about the molecular changes responsible for degradation. Air alone apparently does not cause any noticeable change in textile materials in the absence of other stress factors, but it is rare for all other potentially harmful sources of degradation, such as moisture, light or microbiological agents, to be absent.

There are many ways in which changes occur. Heat and light, separately or in combination, can bring about problems. Each can damage materials, and the combination can cause enough tendering, brittleness or discoloration to render fabrics unusable. A fabric can be exposed to both conditions simultaneously in, for example, the process of drying or ironing.

The contact of fabrics with swimming pool chemicals can also bring about degradation. The chlorine or other disinfectant present can make fibres weak or brittle, shortening the useful life of the article, whether a garment, a liner or a cover.

Fabrics left on or near moist ground quickly experience microbiological growth, a change that it is crucial to counteract for succesful use of such technical fabrics as geotextiles, tentage or horticultural plant covering cloth. Natural fibres, less resistant to microbial agents, tend to rot, visible changes being discernible within days. Synthetic ones, lacking substituent groups used by these agents as food, resist weakening, but may be discoloured. Changes in pH, during perspiration or anaerobic decomposition, for instance, can cause weakening, again usually in natural rather than synthetic fibres. Architectural fabrics, flags, tents and tarpaulins exposed to sun and movement arising from wind force can be torn or tendered. Thus, degradation is all-pervasive and can have drastic effects that render fabrics useless.

19.3 Resource depletion and pollution

The textile industry is one of those that are blamed, often unfairly, for the general decline in the planet's health, and before considering the effects that textile production and use have on ecology, the following terms are defined:

1 The environment: In the context of global harm, the term 'environment' will be restricted to the physical, rather than social, one. The two often impinge on each other, and damage of a physical kind can affect our social environment.
2 Resource depletion: This term is defined as meaning the use of any material present on or within the earth in such a way that it is difficult, or impossible, for it to be recovered without inflicting harm on the planet.

3 Pollution: this is to be understood as meaning the production of any substance or condition harmful to any species, plant or animal on the earth in a manner which is difficult or impossible to reverse without the use of added resources.

19.4 Textile sources of environmental harm

With these definitions in mind, it is possible, in a consideration of textile subjects, to focus on ways in which relevant factors affect the environment. It should be recognised that the production and use of textiles are no more harmful than are those of any other material, and may be less so. There are, nevertheless, ways in which they influence the planet, and these should be considered.

Several papers in the literature deal with this matter. Horstmann[1] notes that environmental hazards in textile production are growing in the finishing sector. He discusses ways of reducing pollution by eliminating or lowering resource consumption, mainly by reusing or recycling goods. Perenich[2] also examines environmental issues in the industry, identifying water quality and use, air quality and emissions and waste minimization as major areas needing attention. Kramar[3] takes a similar view, but focuses on aqueous effluents. He feels that the best way of being environmentally responsible is to reduce the use of water, suggesting that this will cut down both pollution and cost.

Blum[4] takes a slightly more pessimistic view, questioning whether the textile/environment interaction constitutes a threat or a challenge. He feels that it is the industry's responsibility to rise to the situation, discussing political, economic and legal aspects of meeting it. He foresees conflicts between environmental legislation and competition policies, putting his finger on an important issue. Even though the eventual benefits of environmental responsibility can be financially rewarding, there will be an initial outlay of capital to meet higher standards, and this may well force a manufacturer out of business if his competitors do not have to meet the costs at the same time.

It is possible, then, to find harmful effects in the manufacture of fibres, in their subsequent treatment during processing, in their marketing, distribution or use, and in their disposal. The narrow criteria defining harmful practices, normally considered, should not be allowed to restrict our opinion on how textiles bring about ecological damage. Norgaard[5] analyzes the environmental impact of cotton production, recommending the Ecomanagement and Audit System (EMAS) to give quantitative meaning to the process. In addition, Kralik[6] points out that the auxiliary activities associated with the manufacture and use of textile products are often more harmful than the specific textile factors usually considered. Each of the factors relating to environmental degradation should therefore be considered in turn with particular reference to textile applications.

19.4.1 Resource depletion

It is disconcerting to find that the textile industry as a whole does not seem to regard the problem of resource depletion as a serious one. Only one paper in the more recent literature was found to mention the need to use resources effectively, and the reasons are biased more towards economic rather than environmental factors.[4] However, renewable and non-renewable resources alike are at risk from the needs of textile manufacture and marketing. Oil for the manufacture of plastics, water for the manufacturing processes, iron and other metals for machinery or dyes, are all resources which either are not infinite or are finite. Trees are heavily harvested for fibre and paper production and the resulting loss of forest cover must be replaced if the earth's ability to regenerate oxygen is to continue.

19.4.2 Energy consumption

The manufacture, distribution and use of energy are also responsible for resource depletion in the form of the fuels (or oxygen) in combustion. The apparent plenitude of seemingly clean energy can lull us into a false sense of security that encourages waste, though there is increased awareness on the part of many people that shortages are looming.

The often-voiced assumption that new technology, and especially new energy-generating techniques, will resolve the situation is a vain one. There are serious (usually unrecognized) flaws with all the new methods proposed. Even the 'ideal' and 'clean' generation technique of nuclear energy is receiving less enthusiastic support as plant faults compel closure or redesign. Solar energy falling on the earth is so great that a three-day influx, harnessed completely, would provide enough electricity to meet all needs for a decade. Unfortunately, problems involving the means of harnessing it are not taken into account.

Wind, tidal, or geothermal energy production processes all need bulky, unsightly equipment for the capture, conversion and distribution of energy. In addition, they tend to need frequent replacement because equipment is subjected to severe stresses from weather, changes in temperature or tidal action.

19.4.3 Recycling

In many applications, especially where metals, glass or polymers (including synthetic textile materials) are involved, the recycling process can only slow down, not reverse, damage to the planet. Virtually all recycling, in the sense of making a new product from the waste of an old one (rather than just reusing an old product) needs heat, thus using energy. This brings about resource depletion and produces pollution, even if (a highly unlikely presupposition) that pollution is only carbon dioxide, a greenhouse gas. One form of recycling which falls between the two types and is environmentally friendly is practised within the textile industry. This is the process by which surplus fibres or fibre assemblies are returned to the production train for reprocessing instead of merely being discarded; unfortunately, there may be a diminution of properties (such as fibre length, yarn evenness or fabric strength) as a result, which can lower the quality of goods that can be produced from this recycled material. The effects of using reworkable waste on yarn quality, for instance, include a significant reduction in yarn tenacity.[7]

19.5 Textile sources of pollution

19.5.1 Introduction

It is now time to discuss how discarded substances find their way into the environment as contaminants, together with the reasons behind the concern for their presence.

The textile industry is a complex one. The production, coloration, finishing and distribution of fibres, yarns or fabrics are carried out with the aid of large, complicated, expensive machines and a range of chemical substances. The difficulties inherent in manipulating the textiles mean that there are many opportunities for materials, either textile components or reagents added to them, to escape from the equipment. It is this difficulty in maintaining control over movement of materials that is responsible for pollution. Inevitably, the effort to produce all the goods needed leads to the dispersion of impurities into the air, water or land, as well as to undesirable noise levels or visual ugliness. These can be considered in turn with a view to establishing how much responsibility the textile industry must bear in each case.

19.5.2 Air pollution

Air pollution within the textile industry affects people, machinery and products. There is an increased incidence of health problems, especially byssinosis, tuberculosis and asthma,

Air pollution can also arise from use of textiles after manufacture. For indoor furnishings, many pollutants are related to building materials,[8] but furniture, carpets, draperies and wood or fabric furnishings probably give rise to more consumer complaints. This may be because of the presence of formaldehyde or volatile organic substances from wood and office furniture. Guidelines on chemical levels are available (though they do not cover non-industrial buildings), but research to investigate biological pollutants (potentially of more interest in the textile context) is much less extensive.

Secondary emissions from floorcoverings include harmful substances (especially formaldehyde) given off, for example from back coatings. Tests which can be carried out in order to provide a 'green' certification for carpets using suitable chemicals, processes, dyes and colorants are slowly becoming available.

Textiles can, though, play a valuable rôle in contributing to the reduction of air pollution. Many types of filter fabrics are produced, with an ability to remove particles with a range of sizes. The fine pores in a fabric are ideal for preventing the transmission of impurites while allowing air flow to take place. Filter fabrics, indeed, form a major class of technical fabrics and are used throughout the world in all kinds of situations.

19.5.3 Water pollution

Water pollution is more apt than any other type of pollution to be associated with the textile industry by the general public, mainly because, when it occurs, evidence of its existence in the form of coloured dyestuffs from dyeing and printing or detergent foam from scouring or washing is clearly visible. There are, though, other sources of water pollution generated by textile production.

Pollution in wet processing has reached alarming levels, and measures are being developed to reduce water consumption by changing or modifying processes, by lowering the concentration of waste products in water, by using only the optimum quantities of dyes or chemicals of an ecofriendly nature, and by carrying out appropriate restorative treatment. Using less water in manufacturing, reducing the number of steps in bleaching, and recovering chemicals from waste streams reduces both costs and pollution.

Sizing agents and starch are frequently considered to be the most serious sources of pollution in the textile industry, primarily from the volume of emissions present. The total cost of desizing is about 2.1 times the cost of sizing and is responsible for 3–4% of the cost of a loom state fabric. Starch/PVA (polyvinyl alcohol) size discharge can easily exceed legally permitted levels.

In the public mind, though, it is almost always the dyeing process which is associated with textile pollution, particularly with metals such as chromium, cobalt, nickel and copper. The dyeing process itself, possible substitutes, alternative reactive or acid dyes, and ways of minimizing residual dyestuff content may all be able to make some contribution to the overall aim of ecological improvement.

Natural dyes are not without their environmental problems and colour removal does not necessarily mean toxic substances have also been removed; the carcinogenic and toxic effects of dyes are of crucial importance. Mutagenic changes caused by ingesting textile effluents may mean that toxic effects will still be present after biological treatment, a fact which may form a basis for selecting dyes and chemicals for textile plants.

Many finishes can produce pollutant byproducts in the water stream. The use of oils, resins or other chemicals in finishing treatments is so diverse and so widespread that it is impossible to consider them all in a brief survey of this kind, but the application of flame-retardant, softening, durable-press, antistatic, soil-release, stain-resistant, waterproofing or oil-repellent finishes invariably uses materials which are harmful to the environment if discarded. Loss of lubricating or spinning oil from machinery can result in the accidental release of harmful substances, and spillage of diesel or other fuels from vehicles can occur. All of these products can bring about harmful side effects in either or both of the two ways mentioned earlier, by the poisoning of aquatic life or the enhancement of species such as algae, which remove oxygen from water and deprive aquatic creatures of this vital element. Waste discard of other kinds, from floor sweepings to excess chemical leachate from containers, can find its way into streams, either during a storm or by careless handling in cleaning or tidying. As mentioned earlier, an entire industry involving technical textiles has developed with the sole purpose of constraining, as far as possible, damage brought about by such unfortunate polluting events.

Again, textile effects on water pollution are not entirely negative. Indeed, one of the most important developments of the past few decades has been the use of geotextiles to contain pollution. Industrial waste in harbours and oil spills near sensitive coastal regions have been prevented from causing irreparable damage by the effective use of geotextile membranes to prevent widespread dissipation of the polluting substances, while ditch liners, landfill liners and stabilization fabrics for banks of vegetation have prevented the loss of valuable topsoil and the movement of soil containing pesticides or other harmful reagents into water supplies.

19.5.4 Land pollution

Land pollution can arise when a textile, or a substance used during its production, is thrown away on a landfill site. Fibres or chemicals can be harmful if their decomposition (as mentioned earlier) under the influence of air, water or sunlight produces a toxic agent. It is surprising and sad to see that there is virtually no attention paid to this problem in the textile literature, perhaps because it is so obvious and yet so easily accepted that it seems not to be interesting. Examples illustrating the omnipresence of the problem include a range of toxic breakdown products from materials such as polyester, nylon, or other polymers which have been discarded into the waste stream and find their way into a landfill site. Steps taken to render them 'biodegradable' include the use of starch as a source of bacterial nutrition or the incorporation of a substance decomposed by ultraviolet radiation, both of which facilitate disappearance of the waste material. Unfortunately, ultraviolet decomposition is only effective until the polymer is buried, and breakdown products are not attacked by either biodegradation technique, but aided in entering the soil more rapidly. From there, they can find their way into the water supply, acting as contaminants in the same way as if they had been discarded into a stream initially. Again, the valuable contribution of technical textiles in the form of barriers to this transfer cannot be forgotten, and may well prevent serious escape of pollutants from taking place.

19.5.5 Noise pollution

Noise pollution, ignored as an annoying but essentially harmless nuisance until recently, is becoming of more concern in the general population, though not, apparently, in the textile industry. The impression received from a review of the literature is that all that can be done to reduce noise has already been accomplished, and the residual problem is one that has to be tolerated. High noise levels are still generated in, for instance, twisting, spinning and weaving processes. Unpleasantly loud noise can also arise from the use of vehicles or other equipment in loading, shipping or handling raw materials or finished goods.

There is evidence to indicate that the effects of noise pollution are numerous, the most obvious one being hearing loss. Exposure to high intensity noise leads to deafness, at a rate which increases rapidly as the decibel level of exposure increases. The usual assumption made in legislation is that continuous exposure to a sound pressure level of 90 dB(A) is permissible throughout an eight-hour working day, but that exposure to higher noise levels, or to that level for a longer continuous period of time, must be restricted. This is accomplished by using some kind of derating curve or equation, with permitted exposure time continuously reduced as sound level increases, until no exposure at all is legally permitted at levels of 125 dB(A) or higher.

Other effects of noise exposure are less easily identifiable. There is a growing body of evidence to indicate that high noise levels bring about psychological changes, which may include frustration, carelessness, withdrawal or sullenness. Noise exposure over long periods of time has also been associated with increased absenteeism and even wilful destruction.

As before, textile products (and especially technical textiles) can be of service in controlling the effects of noise pollution. They enjoy widespread use as acoustic absorbent materials to reduce the annoyance of high sound levels for human beings.

19.5.6 Visual pollution

Visual pollution, often not considered as a problem, is in fact all pervasive. Not only are textile materials evident as waste strewn around the countryside, but advertisement hoardings frequently include material intended to increase the sale of these goods. Paper documentation and packaging, or plastic sheets used to wrap textiles displayed for sale, often find their way into landfill sites or are scattered around, from such sites or haphazardly, to offend the viewer by ruining the pristine sight of a peaceful natural vista. Landfill sites themselves, even where they manage to contain the waste goods, are gradually encroaching on more and more of the beauty of the earth and, once they are full, can often not be safely capped for fear of toxic breakdown substances being leached into the water table, as mentioned already. Once again, there appears to be little or no interest in developing research to alleviate the problem.

Textiles, once more, are useful in alleviating the problem by exploiting their aesthetic qualities to beautify our domestic surroundings.

19.6 Effects on the environment

As with all modern industries, substances released into the environment by textile producers are generally not harmless and are likely to have far-reaching effects if their release is at concentrations above safe levels. This limit is difficult to decide, as we do not know that a substance will be sufficiently diluted before it is absorbed by an organism, nor can we be certain that that organism will not concentrate toxic materials before any harm is caused. Hence, the most serious concern should be felt (and is often demonstrated) for the discharge of chemical pollutants into the natural environment via air or water or land.

Special consideration needs to be given to water contamination levels from dyeing, printing and finishing, and there is a need to make available adequate information on the ecological impact of chemical products. Some of the better-recognized problems include abnormal pH levels, suspended or settleable solids, oxygen demand, toxicity, colour, persistent bioaccumulative organic substances, mutagenic chemicals and a fish-flesh tainting propensity.

It is usually accepted that many substances that are discarded in textile production can bring about untold harm to nature. Fish can ingest toxins, can even be killed by them, and birds can be rendered sterile. Even if the lower creatures survive in spite of all these hazards, the potentially harmful contents of their bodies can be transmitted up the food chain to affect human beings. Because of concentration at each stage in this process, the end-consumer is exposed to a relatively high level of toxin that may have similar effects on human beings, in terms of sterility, altered genetic structure, or deformed births, as it could have had on other species.

Animals (including human ones) are also subjected to additional pollution-related risks in the form of long-term exposure to harmful substances, such as carcinogenic or other disease-causing agents, as a result of breathing contaminated air or being exposed to harmful agents. Toxic emissions from solvent spinning or tentering operations, and increased incidence of liver cancer among dyehouse personnel, have been noted and are examples of this type of hazard in the textile industry.

Plants can also suffer from the use of insecticides, herbicides or fertilizers which can cause stunted growth, sterility, or death from disease. Once again, even if the plant does not die, the presence of a harmful material can be passed up the food chain until it eventually reaches human beings and causes them harm as before.

19.7 Environmental harm reduction

In view of the damage which our careless attitude to planetary welfare has brought about in the past when our awareness was much lower, it is hardly surprising that a great deal of effort is being exerted by textile companies to reduce the harm that production is doing to the earth.

The ideas put forward for ecological conservation can be divided essentially into four classes. These are, respectively, the adoption of recycling as a means to cut down resource depletion, the use of ecologically friendly fibres or other materials, a reduction in the amount of pollution produced and improvement in methods of removing pollution after it has been generated.

Technical textiles may provide particular difficulties with respect to recycling. They are frequently used in conjunction with other materials, such as coatings and hardened oils, or as components of fibre-reinforced composites. These end-products may be difficult or impossible to break down satisfactorily into their original constituents, so that the textile polymer would be decomposed by any attempt at recovery. In additon, even where some degree of recovery is possible, the environmental cost of the extensive energy and reagent use needed may make the process prohibitively unattractive. Some use of the undestroyed materials may occur, though; if they are suitable for incorporation into, say, road-bed construction or concrete reinforcement, their chemical inertness and ability to resist mechanical stress may be of considerable advantage.

Ecofriendly textile processing is presented as a global challenge,[9] as ecological criteria are increasingly accepted in all parts of the world in selecting consumer goods and 'green' products can command a higher price. Two aspects of textile production, the limitation of harmful products and the reduction in air or water pollution, should be tackled in particular. Public interest in environmentally friendly processes is increasing, and examples of this trend can be found (in addition to the use of recycled bottles in making polyester) by a tendency to use organically grown cotton with naturally coloured dyes. Caution must be used, though, in order to prevent the real nature of so-called green products being overlooked when the green designation is a marketing ploy rather than a genuine benefit to the environment. Perkins[10] notes the transition towards green management, stating that good environmental management can lead to a quick return on investment. He discusses the new ISO standards in this context. Tyagi[11] discusses the environmental audit process, dividing it into the three sections of preaudit, at-site audit and postaudit. Arcangeli[12] feels that environmental management is here to stay, giving details of British developments and information on how companies can obtain accreditation.

The textile industry's resistance to environmental regulations was initially high[13] because of cost, but hard work has nevertheless been carried out to reduce waste and decrease resource use. Manufacturers have now discovered that waste minimization, as well as providing environmental benefits, can be financially beneficial to the industry. Standards, though, unfortunately suffer from the usual defect of ignoring all but the process for which they are established. Thus, no real account is taken in any of the work mentioned of the environmental cost of supplying the energy to run a plant, or of the way in which the planet is harmed by the extraction of ores to manufacture the steel or other special-purpose elements, like manganese or chromium, needed to improve its properties. The environmental costs of transportation are also ignored.

It is mainly in the area of water improvement that most efforts to reduce pollution are taking place. There is need for a reduction in textile waste water[14] to make manufacturers less dependent on changes in government regulations. Recycling cuts down waste, water use, energy and chemical costs, and Kramar[15] proposes practical solutions for this, suggesting not using water as a substrate, or developing measures to reduce consumption and pollution such as the use of plasma under vacuum, ink-jet printing, or dyeing with supercritical carbon dioxide.

Biotechnology has been recommended to reduce pollution after it has been produced[16] and to provide a cleaner industry, while Frey and Meyer[17] describe a new oxidation reactor that can treat heavily polluted water flows and reduce the consumption of both water and chemicals in textile finishing. They outline problems relating to current in situ disposal installations and give details of the benefits of the new system, which can convert up to 90% of the organic sewage present to carbon dioxide and water, as well as saving 80% of water and 20–30% of chemicals used.

However, most attention is being paid to the area of dyeing, presumably because the problem is seen to be greatest in that process. The recommendations of the Paris Commission[18] on environmental protection introduce sweeping new restrictions with regard to dyeing and finishing processes and the growing conditions for natural fibres. Health, safety and environmental regulations for dyeing have undergone significant changes in the last 25 years[19] and are now a major force in shaping the industrial workplace. Hohn[20] summarises the methods available for treating dyehouse effluent for the purposes of purification, including reductive, oxidative, filtration, dispersion, evaporation and condensation techniques.

A cost/benefit analysis of decolorisation by means of coagulation and flocculation treatment processes[21] indicates that the technique is very effective, but controversial because of sludge problems and ecological objections to the flocculation methods used. Activated carbon prepared from coir pith[22] is used to decolorise waste water from reactive dyes, although other work[23] shows that adsorption of dyes on peat has a similar extraction ability, presumably because surface changes and solution pH are important.

In the finishing area, some work is in progress. Regulations pertaining to exhaust air emissions are so difficult to meet that a compromise may have to be made if finishing plants are to stay operative. Textile manufacturers have to be persuaded that the benefits of complying with existing legislation for clean air are that finishing costs can be reduced significantly if the legal position can be met by identifying processes running optimally from the energy point of view.

19.8 Future prospects

Environmental damage is still occurring despite all efforts to reduce it. Harm cannot be prevented or ameliorated by the development of new energy sources, so we are compelled to face up to the fact that we can only reduce the impact of our activities on the planet by reducing consumption or by reusing goods. In the context of personal textiles, this means that clothing will have to last longer, and will only be discarded when it is worn out, not when it no longer appeals to the aesthetic or fashion sense of the wearer. There is the possibility of using second-hand garments, but it is conceivable that the supply of such articles will diminish as the ability to produce new ones falls, or as the range of styles is reduced. Where technical textiles are concerned, attempts to achieve extended life may well result in the continuation of use past the point where it is safe to do so. The collapse of buildings constructed from architectural textiles, the breaking of ropes in a climbing accident, and the tearing of sails or of a tent in a storm all provide further examples of the type of potential disaster that could occur.

There is current concern regarding textile chemicals, environmental protection and aspects of finishing, and the use of ecolabelling, mentioned already, is seen by various workers as a key to future control of pollution. However, even though environmental demands and ecolabelling may well bring about problems in developing countries,[24] environmental constraints deserve to be paramount in new textile development.

Printing may also require special attention. It seems that ozonation has the best potential for success and will best meet future directives. These are likely to be more restrictive, since conventional treatment times and discharge via municipal systems will no longer be tolerated. It is thus critical to reduce pollution and know exactly the nature and appropriate treatment that any product will need to meet colour removal under more stringent future laws. A word of caution should be sounded. Simultaneous compliance with customers' needs and the requirements of present or future legislation may be impossible and the effort to satisfy both criteria will provide major problems for textile printers and finishers. The total print management (TPM) system is suggested as a means of giving the greatest possible reduction in waste (or its total prevention) in water and printing paste use.

An issue that arises is the effect of environmental demands on fashion creativity. Strong, brilliant colours, modified surfaces and unusual material combinations may be needed at times for fashion, but may be unacceptable ecologically. Designers therefore need help, especially regarding ecological information, from suppliers.

One final approach needs to be mentioned, that of meeting the challenge by using 'waste' textiles in unexpected ways. Suggestions include[25] adopting wool batts in facades of buildings for durable heat and sound insulation, serving also as pollution-binding elements. Textile waste is used in concrete aggregate, where polyamide warp-knit fabric waste gives excellent strength and can be used to provide elasticity in on-site cast concrete, as in road building. Polluted land can be used to grow non-edible crops, such as flax or hemp, and to detoxify land at the same time since metal concentration in the soil is lower after harvest, indicating that toxins must be absorbed. The crop is excellent for the textile industry and as a cellulose source in paper making. There must, of course, be some concern about the final fate of the metals once the fabric is discarded.

The future of textile production capability is also likely to be dependent to a considerable extent on environmental factors. Current predictions are that population levels will approximately double every 35 years or so. While this might be taken as an indication of an increased need for textile goods, the large number of people to feed will also require the use of more land for growing foodstuffs. This will, in turn, mean less available space for growing textile-related crops, especially cotton. Some fibres, such as linen or hemp, may still be produced without any competition from food crops, since they grow on marginal land or in ditches, while wool, or other animal hair fibres, may enjoy the advantage of being able to grow on marginal land, and of providing a ready source of food as well as fibres.

In addition, people consume other commodities besides food. Their needs will strain the world's manufacturing resources (especially oil) to the utmost. In consequence, oil will become a scarce commodity and textile fibres derived from it may be given lower priority than that accorded to other, more easily recognised uses, such as transportation or aerospace, thus preventing or impeding the manufacture of artificial fibres to compound the overall fibre shortage.

Yet the demand for fibres will still exist. Textile goods are essential to human presence in most parts of the world, because we have lost the ability as a species to survive the rigours of climate without some form of protection in the form of body covering. The other reasons for clothing use, adornment, the display of wealth or status, physical or psychological comfort and modesty, will presumably still be important, at least in the foreseeable future. Thus the greatly increased demand stemming from a much larger population base will be extremely difficult to meet. This means that textile materials will have to be much more durable, since they cannot be replaced as often, and that the fashion industry (which depends for its very existence on a rapid replacement schedule of garments) can expect to be drastically curtailed.

New uses are also appearing on a continuing basis for technical textiles. There is an added need for industrial goods based on textile structures. Sporting and outdoor activities are becoming more popular as leisure time increases, and new means of satisfying demands are constantly being sought. The tremendous value of geotextiles is becoming more obvious as industrial expansion occurs and the increased need for environmental protection is recognized.

Still other environmental concerns will affect textile use. As population and consumption rise, so also do resource depletion and pollution production. The planet is already stretched to the limit in coping with the demands placed on it; the continuing onslaught on the tropical forest cover that is so crucial to the earth's ability to replace lost oxygen, for instance, is of grave concern to thinking people everywhere but shows little sign of diminishing. The parallel loss of fresh water and pure air will, it is to be assumed, also continue at an accelerated rate as the population rises, at least until some shock event (such as mass asphyxiation or poisoning) brings the human race to its senses. All industry, not just the textile one, will have to share the responsibility for this increased planetary load, driven essentially by the human greed to consume, so industrial activity will at some point need to be curbed. The exact time at which this will have to take place is unpredictable, but as long as the population rises and no steps are taken to reduce consumption drastically, the end-result of a choice between survival or reduction in lifestyle is inevitable.

Steps that can be taken by the textile industry to reduce global damage include the modification of processes to make them more simple and more labour intensive, because these changes tend to lower energy or resource use and pollution production. The results of this trend, though, will include lower quality products, price increases and a smaller selection of goods, together with an increased importance for durability properties in comparison with aesthetic ones. Marketing will be adversely affected; a reduction in exports will result from the lower availability of goods and the need to reduce fuel consumption, and longer replacement times for existing textile products will have to be accepted.

The future for textile production, and especially for the use of technical textiles, appears to be assured, but the need for preservation of the fragile environment may well become a major cause of concern that tempers the possibility of unfettered expansion in response to the ever-rising demand.

References

1. G HORSTMANN, 'Environmental trends in textile production', *Pakistan Textile J.*, 1996 **45**(2) 58–62.
2. T A PERENICH, 'Environmental issues in the textile industry', *Colourage*, 1996 **43**(8) 19–22.
3. L KRAMAR, 'Environmental opportunities in textiles', 35th International Man-made Fibres Congress, Proceedings Conference, Dornbirn 1996 (Österreichisches Chemiefaser-Institut), Dornbirn, 1996.
4. C BLUM, 'The textile industry and the environment – a threat or a positive challenge? *Asian Textile J.*, 1995 **4**(2) 41–45.
5. L NORGAARD, ' "Green" cotton – lifecycle assessment in textiles', *Niches in the World of Textiles*, Proceedings Textile Institute 77th World Conference, Vol 1, Institute of Fiber, Textile and Clothing Science, Tampere University, 1996, 169–175.
6. M KRALIK, 'Environmental influences decisive for manufacture and application of textile auxiliaries', *Vlakna a Textil* 1995, **2**(2) 55–60.
7. P STRAUSE, C ROGERS and WEI TIAN, 'Influence of reworkable waste on yarn quality', Beltwide Cotton Conferences. Proceedings Conference Nashville, 1996, Vol. 2, ed. P Dugger and D Richter, National Cotton Council, Memphis, 1996, 1334–1335.
8. D FRANKE, C NORTHEIM and M BLACK, 'Furnishings and the indoor environment', *J. Textile Inst.*, 1994 **85**(4) 496–504.
9. R PAUL, J THAMPI and M JAYESH, 'Eco-friendly textile processing – a global challenge', *Textile Dyer and Printer*, 1996 **29**(16) 17–20.
10. W S PERKINS, 'The transition toward "green" management', *Amer. Textiles Int.*, 1996 **25**(5) 62–63.
11. P C TYAGI, 'Environmental audit', *Asian Textile J.*, 1995 **3**(11) 49–53.
12. L ARCANGELI, 'Environmental management – here to stay', *Laundry and Cleaning News*, 1996 **18**(9) 24–25.
13. E J ELLIOTT, 'Textiles' role in the environment', *Textile World*, 1995 **145**(9) 221–222.
14. J J PORTER, 'Reduction of textile wastewater using automatic process control, recycle and filtration', in *Environmental Chemistry of Dyes and Pigments*, eds. A Reife and H S Freeman, Wiley, 1996, 193–214.
15. L KRAMAR, 'To keep clear of water pollution: state of the art and solutions', *Industrie Textile*, 1995 **1266**(6) 44–48.
16. A WILSON, 'Biotechnology for a cleaner textile industry', *Int. Dyer*, 1996 **181**(12) 10.
17. F FREY and M MEYER, 'Cracking industry's wastewater challenge', *America's Textiles International*, 1996 **25**(11) 56–58.
18. ANON, 'Parcom recommendations 94/95 III', *Tinctoria*, 1996 **93**(9) 64–68.
19. H M SMITH, 'U.S. safety, health and environmental regulatory affairs for dyes and pigments', in *Environmental Chemistry of Dyes and Pigments*, eds. A Reife and H S Freeman, Wiley, 1996, 295–306.
20. W HOHN, 'Effluent purification methods for indirect discharge', *Int. Textile Bull.*, *Dyeing/Printing/Finishing*, 1995 **41**(4) 62–67.
21. J JANITZA and S KOSCIELSKI, 'Cost/benefit ratio of chemical coagulation/flocculation/flotation methods for clearing and decolouring coloured textile effluents', *Melliand Textilberichte*, 1996 **77**(10) 684–687.
22. H GURUMALLESH-PRABU and K RAVICHANDRAN, 'Studies in colour removal by coir pith', *Asian Textile J.*, 1995 **3**(8) 53–54.
23. K RAMAKRISHNA and K VIRARAGHAVAN, 'Dye removal using peat', *Amer. Dyestuff Reporter*, 1996 **85**(10) 28–34.
24. A HYVARINEN, 'Environmental demands and ecolabelling', *Textile Asia*, 1996 **27**(4) 90–91.
25. K DOMSTIFT BRANDENBURG, STEGLICH, W LEUCHT and W THUMANN, 'Use of natural fibres for facade elements and process for producing the same', EP 0700477, 13 March 1996.