Talking rot... and mildew on textiles

Settle plate with fungal colonies from textile mill. Courtesy of BTTG

Paul F Hamlyn and Brian J McCarthy

British Textile Technology Group

Nature has evolved some very elegant elementary mechanisms for re-cycling of organic substances in the environment. These processes are normally beneficial. This article describes why microorganisms may attack textiles during production and in use, causing financial losses, and what can be done to prevent this happening.

Biodeterioration has been defined as 'any undesirable change in the properties of a material caused by the vital activities of organisms'. Obviously, not all degradation of materials by organisms is undesirable. When we discard objects that we have finished with, we expect 'Nature' to clear away what has then become refuse. Such degradation is an essential process in the maintenance of the world in which we live, and a means of recycling many of the essential elements contained in these materials. However, when it is an unwanted process, as occurs when rot or mildew affects textiles, then it can be a serious problem to manufacturers and users alike.

Under suitable conditions microorganisms that inhabit soil, water, and air can develop and proliferate on textiles. These organisms include species of microfungi, bacteria, actinomycetes (filamentous bacteria), and algae. Textiles made from natural fibres are generally more susceptible to biodeterioration than are the synthetic man-made fibres. Products used in the finishing of textiles such as starch, protein derivatives, fats, and oils can also promote microbial growth. Microorganisms may attack the entire substrate, ie the textile fibres, or they may attack only one component of the substrate, such as plasticisers incorporated in the material, or grow on organic material that has accumulated on the surface of a product. Nevertheless, even mild surface growth can make a fabric look unattractive by the appearance of unwanted pigmentation. Heavy infestation, which results in rotting and breakdown of the fibres and subsequent physical changes such as a loss of strength or flexibility, may cause the fabric to tear and become unusable. The material is attacked chemically by the action of extracellular enzymes produced by the microorganism for the purpose of obtaining food. However, microbial activity can be minimised by keeping susceptible materials dry, as surface growth will only occur when the relative humidity is high. Therefore, some form of chemical

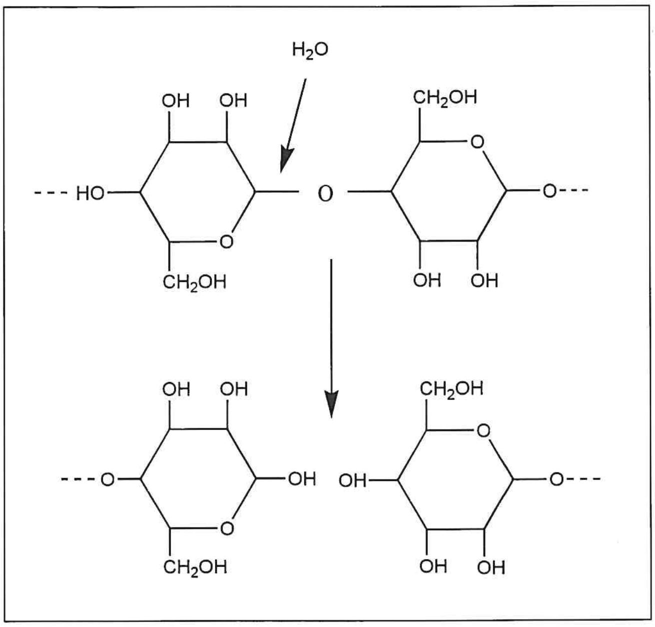

Figure 1: How cellulose is broken down under the influence of an enzyme. The diagram illustrates cleavage of a 'glycosidic' bond in cellulose (a polymer of glucose) by reaction with a molecule of water. This hydrolysis, the fundamental step in the biodegradation of cellulose, which would otherwise be immeasurably slow, is accelerated by the presence of an 'enzyme', or biocatalyst. The insoluble polymer is converted into soluble sugars which can then be metabolized inside the bacterial or fungal cells.

protection is normally only required with textiles likely to be used in adverse conditions under which they remain wet or damp for long periods of time.

Natural fibres

The role of microorganisms as agents in textile spoilage was initially recognised around the turn of the century. Damage to woollen goods as a direct result of microbial activity was reported as early as 1891 following the description of 'mildew spots' present on textile material following storage in damp conditions. Research in this area has continued for many years, with researchers suggesting that the term 'mildew' should be used as a general term to describe the destructive effects of both bacteria and fungi. They recognised that fungal spores capable of producing mildew damage were universal, only needing suitable conditions to develop. They observed that mildew damage may occasionally be attributed incorrectly to other causes, that bacteria and fungi may act synergistically and that split fibre ends may be due to bacterial damage. They concluded that cotton is more readily attacked by microbes than wool, that mildew may affect dye uptake and that substances added during processing may promote mildew growth.

Plant fibres such as cotton, flax (linen), jute and hemp are very susceptible to attack by cellulolytic (cellulose-digesting) fungi. Indeed cellulase enzymes, produced by these fungi, can effect the complete degradation of cellulose. Figure 1 explains the chemical process concerned. The spores of these microfungi are present in the atmosphere and when they settle on suitable substrates they can quickly germinate to produce hyphae which grow on the surface of the material under favourable conditions of temperature and humidity (see Figure 2). The characteristic growth form of these 'mould' fungi is mildew, a superficial growth that may discolour and stain the fabric, as many microfungi are capable of producing pigments. The best protection against mildew is to make certain that the fabrics are dry when stored and that they do not become damp during storage. Algal greening may also occur on fabrics that remain wet for long periods and can cause particular problems in the tropics.

Animal fibres that are proteinaceous are more resistant to mildew growth than plant fibres, which are cellulosic. Wool decays only slowly but chemical and mechanical damage during processing can increase its susceptibility to biodeterioration. When stored under very adverse conditions wool will eventually rot by the action of the proteolytic (protein-digesting) enzymes secreted by many microfungi and bacteria.

Man-made fibres

Man-made fibres derived from cellulose are susceptible to microbial deterioration. Fibres made from synthetic polymers (eg acrylic, nylon, polyester, polyethylene, and polypropylene fibres) are very resistant to attack by microorganisms. The hydrophobic nature of these polymers is probably an important factor determining their resistance. These synthetic polymers also contain chemical bonds, which do not occur or are uncommon in nature, and microorganisms in the environment have not evolved the appropriate enzymes necessary to initiate their breakdown. Although the substance of a synthetic fibre by itself will not support microbial growth, contaminants of low molecular weight (eg residual traces of the caprolactam monomer of nylon 6), and compounds such as lubricants and spinning oils used in the finishing of textiles, may provide sufficient nutrient for mild surface growth of a microorganism. Generally, this will not affect the strength of the fabric but can give rise to staining and discoloration – often difficult or impossible to remove.

Figure 2: Mildew growing on cotton fibre - a magnified view revealed by the scanning electron microscope.

Plastics

Several types of plastic materials have become important as components of textile products, for example, to provide waterproof coatings for rainwear. Plastics, which are made mainly or entirely from polymers such as polyethylene, are usually highly resistant to microbial growth. However, two types of plastic used extensively as coatings for textile materials, plasticised polyvinyl chloride (PVC) and polyurethanes, are susceptible to biodeterioration. In the case of PVC, the polymer itself does not readily provide a source of nutrients for bacteria and fungi. The susceptibility of PVC formulations to microbial attack is related to the amount and types of plasticisers, fillers, pigments, and stabilisers, etc, added during processing. Many of these additives are organic compounds of relatively low molecular weight often capable of being used as food by microfungi. For example, plasticisers (predominantly esters of organic acids, polyesters, and chlorinated hydrocarbons), which are added to increase the flexibility of an otherwise brittle polymer, may support microbial growth. This can have a profound influence on the propensity of the textile coating to biodeterioration; such microbial utilisation of the plasticisers may cause the PVC coating to crack during use. With polyurethanes on the other hand the actual polymer is capable of supporting microbial growth because of the similarity of some of the chemical linkages in polyurethanes to those found in nature. As a practical measure, therefore, biocides are often added to both plasticised PVC and polyurethanes (see Figure 3).

Use of biocides

So far no preservative agent has been discovered which gives complete protection or which is without some disadvantage. Needless to say, the ideal biocide is not yet available and the 'compromise' selection of a suitable product is

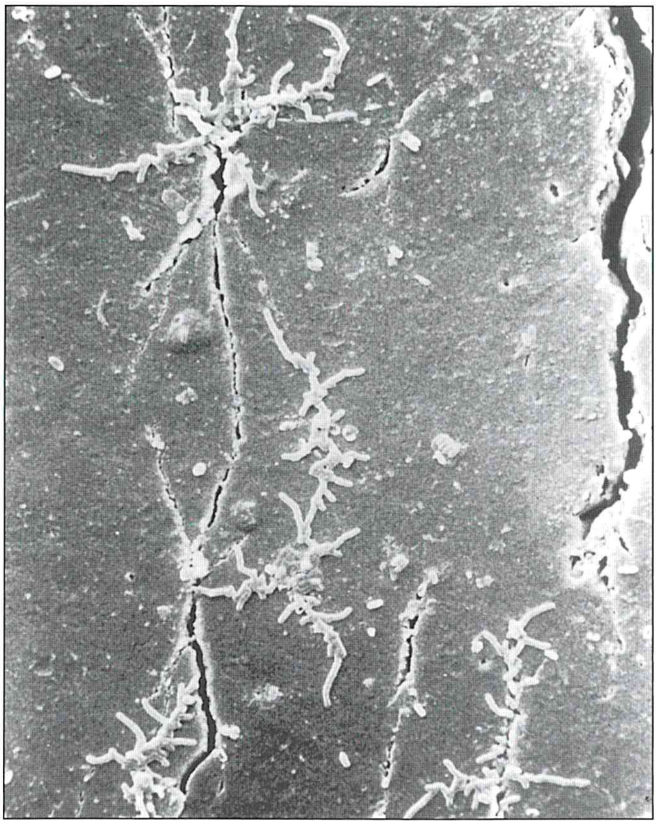

Figure 3: Crack in polyurethane coated fabric caused by microfungal growth.

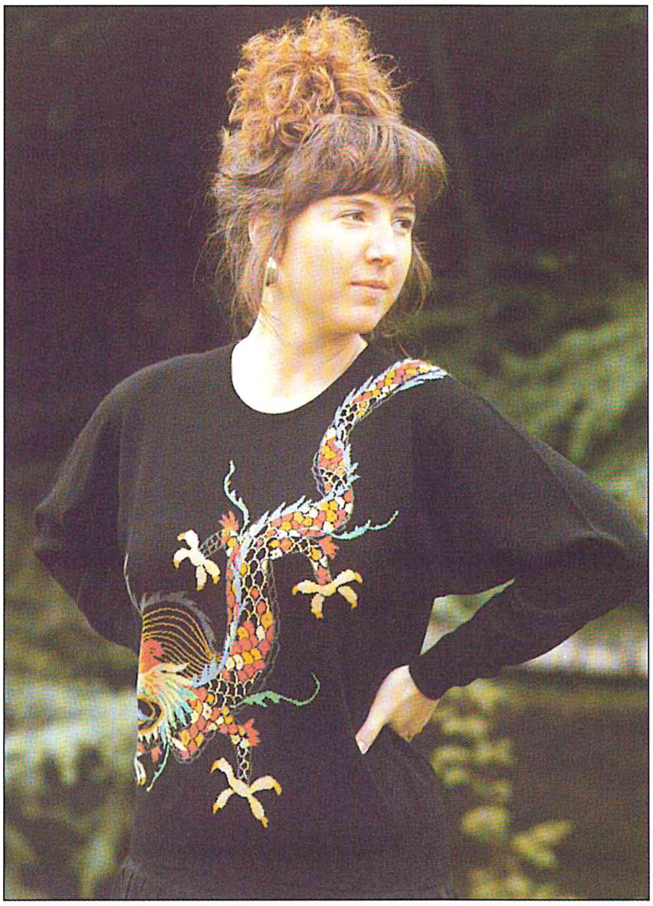

Figure 4: Cashmere sweater.

not always easy. Some chemicals, for example organomercury compounds, have fallen out of favour because of their persistent and cumulative toxic effects in the environment. Textile materials which are to be used outdoors require a stable fungicide that is resistant to being washed out by rainwater and to breakdown by light. If the environment is extremely wet, control of algae and bacteria becomes more important. However, many compounds that are effective against microfungi are not necessarily good bactericides and vice versa.

Application of biocides to textile fabrics for rot and mildew proofing is usually carried out as a final finishing process. Often they are applied together with water-repellents, fire-retardants, and pigments. Biocides are also used to provide hygienic finishes for fabrics that will be used in health-care products.

Quantifying the extent of biodeterioration of textile materials is difficult but it must be measured in terms of millions of pounds sterling annually in the UK alone. Failure of materials can often be a complex phenomenon resulting from a combination of chemical, physical, and microbiological causes. Further research is required into ways of making both natural and synthetic materials more resistant to biodeterioration by chemical modification of their structure, particularly since doubts have now been raised about the toxicity and environmental persistence of some of the hitherto well established biocides. It is likely that improved biocides will appear on the market to meet new regulations.

The authors are scientists working in Quality and Innovation for the British Textile Technology Group, Shirley House, Didsbury, Manchester M20 2RB.