Section 4: New Products and Processes

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OEKO-TEX LABELLING OF TEXTILES

Erich Zippel

THE CONCEPTS OF ECOLOGY AND ENVIRONMENTAL LABELLING

Textile industry and environment

The textile and clothing industry is a very important field of industry. It produces not only the second skin - clothing - for about 7 billion people but also contributes to human's third skin - housing - quite a lot.

Raw materials for textile products are vegetable fibres such as cotton, flax etc., animal fibres such as silk, wool, and other animal hair. Additionally, the residual products of the oil refining and the petrochemical industry and wood-pulp industries are used for the production of viscose and chemical fibres. The fibres are processed to consumable products by textile industry by means of spinning, weaving, knitting, finishing and making-up.

Having a fibre production of approximately 40 million tonnes (1990), the textile industry with its respective suppliers is internationally interlocked as probably no other industrial sector. Cotton is grown in 70 countries, with special emphasis in USA, India and the newly independent states and Russia. Wool comes mainly from Australia and New Zealand, but also from Western Europe and South America. Main synthetic fibre production is concentrated in USA, Western Europe and Taiwan with increasing shares of Indonesia and South America. Up to 80% of the textiles on the market in some Western European countries are imported from other countries.

Any textile production - from fibre to garment production - influences the environment to a higher or lesser degree. Textile industry has responsibility for the impacts of their activities to the environment. There is needed a clear concept of reducing those environmental problems, taking into account the international interconnectivity.

Ecology

Ecology is the science of the relations of human beings to their environment. It is useful to split the topic "ecology in the textile industry" into three separate steps.
Production ecology deals with the effects on the environment during the production of textiles.
Human ecology / Ecology of use deals with substances harmful to the consumer which textiles may contain and environmental impacts during use
Disposal ecology deals with an ecologically beneficial disposal of worn out textiles .

Environmental labelling systems

The environmental labelling of products as proposed by authorities and consumer protection organisations, aims at the introduction of such a label for all kinds of goods including textiles. All issues of ecology should be included in the evaluation for the labelling in a "cradle to grave" approach. Such labels are for instance the "Blaue Engel" in Germany, the "Österreichische Umweltzeichen", the Dutch "stichting milieu keur" or the "Nordic Swan" in Scandinavia. Such national labels, if covering textiles at all, are only of some significance in the countries of origin. The same intentions are the basis for the decree of the eco-label of the European Union.

There are also many marketing strategies using company-specific "private labels". The advantage for the company is that such statements are not controlled and that one saves the cost of testing. Other activities in the textile labelling field start with ambitious, but mostly not very fashionable and colourful eco-collections labelled with slogans like "not bleached", "no chemical auxiliary materials", or "dyed with natural colours," appeal to a very limited clientele.

The third approach is the one Oeko-Tex uses. First of all textile ecology is far too complicated to cover it all by just one set of simple criteria from cradle to grave. Secondly a trustworthy label is based on testing and not on declaration by the company. Thirdly, a proper textile labelling scheme is not a barrier to trade. And last but not least, a labelling system has to be based on a set of written, available rules and requirements, in other words,a standard.

THE OEKO-TEX STANDARD 100

The International Association for Research and Testing in the field of textile ecology (Öko-Tex), was founded five years ago by the Austrian Textile Research Institute - ÖTI - and the Forschungsinstitut Hohenstein. The group currently consists of 12 textile institutes all over Europe.

The Oeko-Tex Association issues the Oeko-Tex Standard 100, which, based on earlier work of the ÖTI, issues the "Oeko-Tex Standard 100".

This document lays down the criteria for human-ecologically safe products. Limiting values for toxic substances that can be contained in textiles are described for different textile product classes. Pre-products, intermediates and final products can be submitted. After successful testing, installing a sufficient quality control system and issuing a conformity declaration a license for using the registered Öko-Tex 100 label (Figure 1) can be granted.

The standard contains a wide set of parameters and limiting values for harmful substances that can be contained in a textile product as depicted in Figure 2.

Figure1: Oeko-Tex Standard 100 labelling

Figure 2: Oeko-Tex Standard 100 limiting values

Grenzwerte und Echtheiten / Limit values and fastness / Valeurs limites et solidités

Produktklasse - Product class - Classe de produits	I	II	III	IV
	Baby / Baby / Bébé	mit Hautkontakt / in direct contact with skin / en contact direct avec la peau	ohne Hautkontakt / with no direct contact with skin / sans contact avec la peau	Ausstattungsmaterialien / decoration materiel / matériel de décoration
pH-Wert / pH value / valeur pH[1]				
	4.0 - 7.5	4.0 - 7.5	4.0 - 9.0	4.0 - 9.0
Formaldehyd / formaldehyde / formaldéhyde [ppm]				
Law 112	20	75	300	300
Emission / emission / émission[2]	0.1			0.1
Extrahierbare Schwermetalle / extractable heavy-metals / métaux lourds extractibles [ppm][3]				
As (Arsen / arsenic / arsenic)[4]	0.2	1.0	1.0	1.0
Pb (Blei / lead / plomb)	0.2	1.0	1.0[5]	1.0[5]
Cd (Cadmium / cadmium / cadmium)	0.1	0.1	0.1[5]	0.1[5]
Cr (Chrom / chromium / chrome)	1.0	2.0	2.0	2.0
Cr(VI)	nicht nachweisbar / under detection limit / selon la limite de détection[6]			
Co (Cobalt / cobalt / cobalt)	1.0	4.0	4.0[5]	4.0[5]
Cu (Kupfer / copper / cuivre)	25.0[5]	50.0[5]	50.0[5]	50.0[5]
Ni (Nickel / nickel / nickel)	1.0	4.0	4.0	4.0
Hg (Quecksilber / mercury / mercure)[4]	0.02	0.02	0.02	0.02
Pestizide / pesticides / pesticides [ppm][4]				
Summe / sum / total (inkl. / incl. PCP/TeCP)[7]	0.5	1.0	1.0	1.0
Chlorierte Phenole / chlorinated phenols / chlorophénol [ppm]				
Pentachlorphenol (PCP)	0.05	0.5	0.5	0.5
2,3,5,6-Tetrachlorphenol (TeCP)	0.05	0.5	0.5	0.5
Farbmittel / dyes / colorants				
Abspaltbare Arylamine / cleavable arylamines / arylamines dissociables[7]	nicht verwendet / not used / pas utilisés[6]			
krebserregende / cancerogenes / cancérigènes[7]	nicht verwendet / not used / pas utilisés			
allergisierende / allergenous / allergènes[7]	nicht verwendet / not used / pas utilisés[6]			

1 Those products which must be treated wet during the further processing can have a pH value within 4.0 - 10..5
2 For carpets, mattresses and articles coated with foamed materials only
3 For class I using an artificial saliva soluiton, for class II - IV using an artificial acidic sweating solution
4 For natural fibres only
5 No requirement for metallic accessory
6 Quantification limits: for Cr(VI) 0.5 ppm, for arylamines 20 ppm, for allergenous dyestuffs 0.006 %
7 For a compilation of the individual substances see annexe 6

Produktklasse - Product class - Classe de produits	I Baby / Baby / Bébé	II mit Hautkontakt / in direct contact with skin / en contact direct avec la peau	III ohne Hautkontakt / with no direct contact with skin / sans contact avec la peau	IV Ausstattungsmaterialien / decoration materiel / matériel de décoration
Chlororganische Carrier / chlorinated organic carrier / carrieur chloro-organique [ppm][7]				
	1.0	1.0	1.0	1.0
Biozidausrüstung / biocidic finish / apprêt biocidique				
	keine / none / aucun			
Flammfestausrüstung / flame retardent finish / apprêt ignifuge				
	keine / none / aucun			
Farbechtheiten (Anbluten) / colour fastness (staining) / solidité des couleurs (dégorgement)				
Wasserechtheit / towards water / à l'eau		3	3	3
Schweissechtheit, sauer / towards acidic perspiration / à la sueur acide		3 - 4	3 - 4	3 - 4
Schweissechtheit, alkalisch / towards alcalic perspiration / à la sueur alcaline		3 - 4	3 - 4	3 - 4
Reibechtheit, trocken / towards rubbing, dry / au frottement, sec[8]	4	4	4	4
Reibechtheit, nass / towards rubbing, wet / au frottement, humide[8]	2 - 3	2 - 3	2 - 3	2 - 3
Speichel- und Schweissechtheit / towards saliva and perspiration / à la salive et à la sueur	echt / resistent / solide			
Emission leichtflüchtiger Komponenten / emission of volatiles / émission de composants volatils [mg/m³][2]				
Toluol	0.1			0.1
Styrol	0.005			0.005
Vinylcyclohexen	0.002			0.002
4-Phenylcyclohexen	0.03			0.03
Butadien	0.002			0.002
Vinylchlorid	0.002			0.002
aromatische Kohlenwasserstoffe aromatic hydrocarbons hydrocarbures aromatiques	0.3			0.3
flüchtige organische Stoffe organic volatiles composants organiques volatils	0.5			0.5
Geruchsprüfung / Determination of odors / Détermination du gégagements d'odeurs				
Generell / general / en général[9]	kein aussergewöhnlicher Geruch / no abnormal odor / pas d'odeur inhabituelle[10]			
SNV 195 651[11]	4			4

THE OEKO-TEX STANDARD 1000

There are two philosophies for how to achieve a better environmental performance of a company. On the one hand improvements can be achieved by external pressure applied, i.e. legal requirements or other regulations defining exact goals for environmental protection. On the other hand, systems can be promoted, which yield a permanent

8 For pigment, vat or sulphurous dyes a minimum grade of colour fastness to rubbing of 3 (dry) and 2 (wet) is acceptable
9 For all articles with the exception of textile floor coverings
10 No odor from mould, high boiling fraction of petrol, fish, aromas, or perfume
11 For textile floor coverings only

improvement of the environmental performance of a company using the resources at hand.

A possibility of achieving such environmental improvements and of verifying and showing them to the public, is the participation in environmental auditing and certification schemes like the *Öko-Tex Standard 1000*, the ISO-standard 14000 series or the EMAS-system of the European Union.

As the environment and environmental destruction obey no borders, it should be in every single person's interest to contribute to an improvement of the global environmental. A possibility open to the consumer but also to the retailer and the producer is an evaluation of his sources of supply in regard of their respective environmental performance.

Although the legal environmental requirements and the overall environmental standards are lower in the low wage countries, the range of environmental performances of the single companies differs from no environmental measures at all to being at the highest levels. Furthermore attempts to improve the situation are as intense, or even more intense, as in countries with developed environmental protection systems. An evaluation of suppliers in respect to their environmental performance helps such efforts, as the ones who are willing, get an opportunity to demonstrate and exploit their achievements.

Kinds of labelling systems for production ecology

When evaluating the environmental impact of industrial activities, two fundamental approaches are possible.

On the one hand the production process can be taken into account and on the other hand, there is the product itself to be evaluated.

Production Site Evaluation

The evaluation of production processes and production sites is more straightforward, as there are defined modules in respect of place, time and technology. Quantifying such an approach for the amount of products crossing this process, there are also included a part of the life circle of this product and all the different later final products formed out of it. Such modules can then be joined together brick by brick.

The assessment of the environmental impact of the production site and a classification as "environmentally sound" not only shows the high environmental standards in production, but it also forms an integrated part of a product evaluation.

Product Evaluation

An evaluation of the complete life of a product from "cradle to grave" or a "life cycle assessment" enables, in principle, a comparison between different products. Nevertheless, the scientific basis and the practical approach are rather laborious. Especially difficult is the definition of the amount of detail necessary and the evaluation of the factors which are insignificant for the result.

The concept of the Öko-Tex Standard 1000

The aim of the Standard 1000 of the *Öko-Tex International* is an evaluation of the environmental performance of textile production sites and products and to document independently that certain environmental measures are undertaken and a certain level is achieved.

Production Site and Product Audit

The system of Öko-Tex Standard 1000 is based on auditing the environmental performance of textile production sites as well as evaluating textile products for their environmental sound production.

Part A of the Standard contains the requirements for certification of production sites, Part B covers the requirements for labelling of textile products.

Environmental management and limiting values

An essential feature of environmentally sound production is its continuous redefinition based on new research results and new technological opportunities. An efficient possibility to improve the overall environmental performance of produced goods of a company is the implementation of an environmental management system.

In addition to environmental management measures, detailed technical requirements for the achievement of a common environmental minimal standard are given. They may be divided in prohibitions, when some chemicals and production techniques are no longer acceptable in terms of an environmental friendly production due to health as well as environmental risks, and in values which have to be controlled continuously.

These requirements do not only give a minimum basis but they may also be used by the company as a guide to find out the priority fields for environmental action.

Advantages of the Öko-Tex Standard 1000

The Öko-Tex Standard 1000 system has several advantages compared to certification systems for environmental management like the EU EMAS System.

- The Öko-Tex Standard 1000 is available not only for Europe but all over the world.
- The Öko-Tex Standard 1000 does not only demand procedures but gives clear criteria and limiting values for testing and auditing of textile, clothing companies and ancillary industries.
- The Öko-Tex Standard 1000 extends the human-ecological testing in conformity with the Öko-Tex Standard 100 by the inspection of the ecology of production.
- The product certification according to Öko-Tex Standard 1000 extends to all links of the production chain and therefore allows for evaluation of the formation of the product. The EMAS system only evaluates a single production site.
- Certificates for preliminary products according to Öko-Tex Standard 1000, Part B, can be used as easy proof when buying material for a variety of certified textile products.
- The Öko-Tex Standard 1000 states an increased level of protection for the consumer as the products of a certified production site also correspond to the requirements of human ecology with regard to toxic substances.
- The Öko-Tex Standard 1000 permits throughout all textile production a labelling on the final product, which reaches the consumer.

ENVIRONMENTALLY CONSCIOUS TEXTILE DESIGN: TOWARDS A NEW APPROACH

Jo Heeley

INTRODUCTION

This paper focuses on the environmental implications of textile design specifications. Drawing on the author's own PhD research findings, it will assess the extent to which environmental issues are considered within current textile design practices, and discuss some of the obstacles to integrating environmental concerns at the present time. Finally, a number of recommendations are put forward with reference to other recent research, which could enable environmental issues to be incorporated into the design decision-making process.

TEXTILE DESIGN AND THE ENVIRONMENT

To date, environmental issues have been dealt with mainly from the manufacturing site, and at management level. Action appears largely to be compliance driven, and emphasises waste minimisation, and end of pipe pollution controls. In future, the cost of effluent treatment will rise, and manufacturers will need to start concentrating on eliminating waste by dealing with the problem at the design concept stage when products are being formulated rather than at the production stage.

The idea of designing products from the outset to minimise waste at its point of use and through its entire life-cycle has so far not been considered within the textile industry. Yet, there is growing awareness that the pace of demand for products and processes with environmental sensitivity is increasing, and that there is a real need for higher levels of environmental awareness for product development in the future. If we consider that much of the environmental impact of a product is determined at the design stage especially when selecting materials and manufacturing processes (70% of product costs are determined or built in at the design stage), in theory this proactive approach eradicates the need to clean up pollution at the end of a products life [1,2].

In practice, research findings have shown that environmental considerations are seldom a factor in determining how or if a product is made and designers often appear remote from the consequences of their specifications which may impact significantly on the environment [3-6]. As Wiberg [6] remarks:

"The designers, separated from the production, are busy with the artistic, the visual and the symbolic. The emphasis on the needs stated by the producer and the focus on the visual have, indeed, had most contradictory consequences....What about the materials used, the finishes and production methods and their effects on the environment?"

Traditional textile design training has concentrated on designing the visual elements of new products, emphasising the importance of aesthetics and artistic experimentation with little consideration of production capabilities and environmental factors. As Jackson [7] explains, *"it is still perceived by many inside and outside its practice as icing rather than* *cake - something pleasing but unessential."* This model of designing can be said to distance the designer from self-examination or social responsibility [8].

Obstacles to intergrating environmental issues into the design process

During the course of this PhD research, interviews were undertaken throughout the textile and clothing industry in order to determine the attitudes and actions of designers to consider environmental issues. Interviews took place with textile manufacturers and processors, environmental managers, designers (in-house, as well as freelance designers working on eco-textile collections) suppliers, trade associations, and regulators in order to obtain a range of viewpoints. Findings revealed that companies do not appear to recognise the importance of the designer's role in providing solutions to environmental problems and there was generally a poor perception of the importance of the designer's role. Numerous barriers to the implementation of design specified environmental measures were identified. Some of the main ones included:

- time pressures;
- lack of environmental information/specialist knowledge;
- lack of awareness of environmental issues;
- weak link between designers and manufacturers
- weak link between designers and environmental personnel
- viewed more as future practice.

These points are briefly discussed below.

Lack of environmental information/specialist knowledge

The majority of designers interviewed felt it was difficult to choose designs on the basis of one having less of an impact on the environment than another. Within current textile design practices the emphasis is on appearance with little consideration of production capabilities and environmental factors as they impact on their design decisions. Designers considered they were not adequately equipped with the suitable knowledge and skills to help to improve the environmental performance of textile products. One retailer commented:

"One of the problems is if you say to a designer, design me something which is environmentally friendly, they haven't got a clue about what scale of measurement you can use to say what design is better."

Numerous manufacturers suggested that designers should be more aware of the technical side of production issues. As one trade association representative commented:

"Designers have to look at life anew almost, and the problem with designers is that they don't know the textile side too well. They are going to have to learn a lot of technology which has never really been necessary before. The designer needs to know what can and can't be recycled if the fibres are mixed together. Is the cotton that you sew up with the same cotton as the garment? If leather patches are added, can they be recycled? Pure fabrics are easy to recycle, once you start mixing things it is very difficult."

It was widely considered that at the present time, the more traditional arts based design courses were not equipping designers with adequate technical skills to understand the environmental implications of their design decisions.

Lack of environmental awareness

The research revealed that few designers were aware of environmental factors relating to their design specifications and that despite reasonable awareness of the perceived benefits of incorporating environmental factors into design decisions, environmental concerns are not a priority at the present time. This could be due to the fact that designers felt they are presently not affected by the environmental constraints imposed on manufacturers since they are not involved in the dyeing and finishing stages and cloth production. Some designers did not feel it was their responsibility to consider the environmental impact of processes and products, and they did not seem to feel they could contribute to improving environmental performance. It was commented that these were issues for environmental personnel and production departments.

There was some evidence of environmental awareness among designers evident in their knowledge of the ranges of eco-collections being promoted in the marketplace, but there appears to have been little action taken to improve environmental performance of textile products.

Weak links between designers and manufacturers/technologists

The research revealed that whilst the textile industry has had to address the pollution problems caused by the processing of textiles, the fashion industry and in particular designers and trend forecasters, appear to have focused on the product itself and green textile and fashion products have appeared in designer collections and more recently in high street stores. Manufacturers argued that the designers' promotion of eco-friendly fashions has largely confused or hindered any real environmental improvements as little consideration has been given to how the yarns, fabrics and colours are made, and the associated environmental impacts.

It became evident over the course of the research that significant communication problems exist between designers and technologists. It seems the main problem is that it is difficult to understand all the issues involved if you do not have a technical background. The theoretical basis for language on which each of these specialists has been educated varies considerably, and it was widely argued that there is a real need to find areas of common ground and to work together more effectively.

Weak links between designers and environmental personnel

The research revealed that at the present time there appears some considerable distance between the environmental manager and the product development process. A recent survey by Charter and Chick [9] also showed that both design and sales/marketing came low down the list of priorities of environmental managers who are typically more concerned with emissions and compliance. Speerli and Zust [10] suggest a closer relationship between designers and the tasks of environmental managers is necessary in order to achieve an overall improved environmental performance within companies. They argue that designers must play a key role as it is at this stage that most product characteristics (durability, recyclability, product cost, etc.) are determined.

Time pressures

With the constant pressure of meeting deadlines and reducing lead times in getting the product to market, a number of designers suggested it would be difficult to justify long time scales whilst they try to accumulate this 'new' knowledge.

Viewed as future practice

Whilst at the present time designers do not appear to play a significant role in minimising the environmental impact of textile manufacturing activity, it was widely commented that the design stage is where there is the greatest potential to design out pollution. Therefore numerous respondents suggested that in the future design would start to play an increasingly important role.

Importance of the designer's role

The concept of cleaner production, of designing out pollution, has so far been based on the assumption that the solution is mainly technologically driven. Existing process technology is being modified, and harmful substances are substituted for less damaging ones. As concern for the conservation of resources grows, increasingly designers will be encouraged to consider the environmental impact of their design decisions. In other sectors, notably electronics, and the IT industry, environmental factors are being considered early on in the product development process with some success. This is beginning to result in products which have a minimal environmental impact, achieved often through the use of multi-functional teams in the product development process.

Designers have a key role to play as they are the industry's connection to the marketplace, dealing with the use and experience aspect between the product and the person [11]. Therefore, integrating the environment into a products overall marketing and communication strategy could be an important role for designers in the future. If we take the Packaging and Waste Directive as an example, packaging designers have to consider reducing the amount of materials, and to communicate environmental information to the consumer, ie, with disposal instructions. It is therefore not only up to the designer to create design concepts that meet environmental criteria, but also to communicate to the consumer that their products are responsibly designed, manufactured and packaged.

DEVELOPING ECO-DESIGN STRATEGIES, METHODS AND TOOLS

If textile and clothing designers are to influence our patterns of consumption they need information on the environmental impact of the processes and materials they use and be aware of appropriate changes in materials, processes, and disposal routes [4]. It is important to see the whole picture of the 'life cycle' to prevent advantages in one stage being offset by impacts elsewhere, and to enable designers to make informed choices about the positive and negative impacts of the materials and resources they use. Eco-design is the term used to describe the systematic approach that attempts to reduce and balance environmental inputs at each stage of the life-cycle of a product from raw materials extraction to eventual disposal. Other industrial sectors such as electronics and the IT industry have begun to consider environmental factors early on in the product development process, offering new opportunities for competition, and new environmentally conscious products to enter the market.

There are few developed and reliable strategies for decision-making based on environmental criteria, though considerable research is underway to develop supporting tools and techniques for learning. Some of the eco-design tools and methods which have been developed to date include: lcas, ecodesign matrices, checklists, databases and software programmes. See Table 1 below.

Table 1: Eco-design tools

LCAs - life cycle analysis lifecycle of product divided into material extraction, production, use, distribution, disposal	• guide decisionmakers in choosing actions which minimise environmental impacts throughout the lifecycle of products • presents whole picture, preventing advantages in one stage being offset by impacts elsewhere • provides a framework for the necessary corrective actions • problems - time-consuming, complex, once all the data is collected not always sure what to do with it
Eco-design matrix	• grown out of lca though more proactive • attempts to identify design approaches that can prevent the problems occuring • shows possible environmental impacts, suggests various design options • time consuming, requires considerable additional research
Computer tools	• calculate all environmental impacts taking place during the products life cycle, can deal with large quantities of complex data, quickly and accurately

However, before these eco-design tools and methods can be applied in the textiles sector, similarities and differences in the way different sectors approach product development must be identified and the tools and the methods adapted accordingly. Research is therefore required to examine the practical applications and limitations of eco-design tools, drawing on examples of successful implementation in other industries, and identifying ways to successfully implement eco-design strategies in the textiles and clothing industries. The author is currently involved in a government funded research project entitled, "Concurrent product development with design for environment in the UK textile and clothing industry." This new research project which runs from Dec 97-99, will explore the use of multi-disciplinary teams to achieve concurrency[a] and environmentally

[a]Concurrent product development is a design approach which involves the earliest possible integration of design, marketing, manufacturing and sales expertise and knowledge in creating new products (Shin, 1991).

conscious design in the new product development process, drawing on examples from other sectors, in particular electronics. A second paper is presented in these proceedings which addresses this project [12].

RECOMMENDATIONS FOR FUTURE INITIATIVES

This section suggests a number of methods which could enable environmental concerns to be incorporated into the design decision-making process. The ETBPP (1997) present a number of recommendations for improving the flow of environmental information to designers including:

- in-house environmental seminars (using external experts);
- design involvement at in-house environmental meetings;
- an environmental database providing 'instant' data;
- provision of environmental information at trade fairs;
- a regular section in fashion and trade journals;
- better provision of environmental information in design colleges.

Whilst Heeley and Press [13,14] suggest the need to:

- improve communications between manufacturers and in particular with environmental personnel;
- join design-related environmental organisations which encourage the exchange of environmental information, experiences and standards through talks, newsletters and special events. A number of eco-design groups already established include TEN[b],UNEP-WG-SPD[c], EC02[d] and the EDA[e];
- develop more ecologically sustainable designs, promoted at national and international exhibitions and trade fairs;
- broaden design skills and experiences to include understanding of manufacturing and production capabilities, and a responsibility and understanding of the environmental and social consequences of the materials used;
- ensure designers are familiar with environmental legislation and political concerns which affect their company's processes and products;

McAloone and Evans [15] suggest that if environmental factors are to be integrated into the product development process the information must be quick and simple to incorporate for, *"if the method of embodiment of environmental concerns into design is alien to the designer or cumbersome to carry out, it will not be adopted."* They argue that whilst we need to strive for effective long term environmental improvements, in the short term we

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[b]The Textile Environmental Network (TEN)provide an exchange of information and ideas through a programme of seminars, workshops and exhibitions relating to environmental aspects of textiles.

[c]The United Nations Environment Programme Working Group on Sustainable Product Development (UNEP-WG-SPD) stimulate information exchanges through a newsfax, network directory and a magazine.

[d]ECO2 are a group of PhD researchers concerned with ecologically and economically sound design and manufacture. Research discussions take place via an e-mail forum and regular meetings around the UK.

[e]The Ecological Design Association (EDA) links designers of all disciplines, providing an information and communication exchange through their journal, membership directory, newsletter and events programme.

need to also seek short term solutions which can be easily implemented such as 'five minute environmental design tools.'

CONCLUSIONS

The PhD research undertaken by the author revealed that whilst there is some evidence of environmental concern among designers, environmental effects in new product development are not yet seriously considered. In the longer term however, it is likely that environmental solutions will shift from end of pipe solutions to be integrated into the design and manufacture of products and that environmental considerations will be an essential part of the total design process.

Product developers have a crucial role as decisions are made at this stage which others then implement. It cannot be expected that designers should have all the relevant expertise, hence, the growing recognition that the product development process might require greater integration between specialisms including production, design, sales and marketing. Within companies there are are often inherent communication problems between design and other disciplines and functional areas (design, production, and marketing, etc.). The solution is to overcome these functional boundaries and to develop a more holistic and integrated approach to designing and manufacturing products.

A recent initiative by the Environmental Technology Best Practice Programme (ETBPP) has carried out a survey of designers within a cross-section of UK textile and clothing companies, to establish how inclusion of environmental considerations at the design stage could result in cost-effective waste minimisation for the textile industry. There is a real need for further initiatives of this type which recognise the importance of the designers role, and see the designer as providing solutions rather than creating problems in the first instance.

This will undoubtedly mean changing the way designers are educated to ensure design decisions are made within a framework of ecological sustainability. The further and higher education sector plays an important role "as it at this stage that young people begin to link formal school experience with the world of adult life. It is thus pivotal to the establishment of individual attitudes and subsequent actions" [16]. The students of today are the professional designers of tomorrow, and design colleges should be taking on board environmental concerns in order to bring relevant and practical experience to learning, and to increasingly connect with the local community and the environment.

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CONCURRENT PRODUCT DEVELOPMENT WITH DESIGN FOR ENVIRONMENT IN THE UK TEXTILE AND CLOTHING INDUSTRY

Tracy Bhamra, Jo Heeley and David Tyler

INTRODUCTION

This paper provides an overview of the E-Co Challenge project, a DTI Sector Challenge research initiative involving the Manchester Metropolitan University, Cranfield University, and numerous UK industrial collaborators involved in various stages of the textile supply chain and representing a range of company sizes. They are Storehouse Plc, Courtaulds Fibres (TENCEL), Coats Viyella Clothing, Speedo (International) Ltd, Courtaulds Textiles Plc, and Kenneth Fogg Ltd.

This two year research project is concerned with novel approaches to the product development activity particularly, Concurrent Product Development (CPD) and Design for Environment (DfE) practices. Firstly, conventional approaches to new product development (NPD) and some of the inherent weaknesses will be explored. The paper will then go on to introduce the CPD and DfE concepts. Drawing on examples of successful CPD and DfE implementation in other industry sectors, in particular electronics, we will explore some of the potential benefits to the UK textile and clothing industry of adopting this approach.

PROJECT BACKGROUND

The textile and clothing sector is the sixth largest industrial grouping in the UK and provides over 250,000 jobs (9% of total UK manufacturing work force). Over the last decade there has been a growing trend for the UK Textiles and Clothing sector losing ground to cheaper foreign imports (import penetration in the clothing sector was 65% in 1991, and is set to reach 80% by 2001 [1]. These statistics are an indication of the market pressures faced by the sector, and for the urgent need to seek greater competitiveness. To counter the import threat the dominant emphasis within the retail sector has been to improve competitiveness by adopting the Quick Response strategy, bringing flexible deliveries through home sourcing, reduced stock and higher net margins. Manufacturers have also started to respond with innovative design input improving the quality and style of products. This quest for higher value-added consumer products has resulted in a variety of technological and organisational changes.

There are now increasing pressures from consumers, industrial customers, investors and regulators to consider environmental issues. There is also a move by some of the larger retailers to place environmental requirements on their suppliers. The UK textile and clothing industry is facing a similar situation to that faced by the electronic/electrical sector in the 1980s. In these sectors, the use of concurrent product development (CPD) has become a common tool.. Design for Environment (DfE) has also been recognised by the electronics sector in recent years as being essential if they are to compete in a global marketplace where governments are regulating against pollution and environmental damage. As a result there is a wealth of experience from which the textile industry can draw as it now faces a similar situation with increasing external pressures to consider environmental issues.

PROJECT DESCRIPTION

The overall objective of this project is to greatly improve the competitiveness of the UK textiles and clothing sector enabling the move towards improved standards of quality, efficiency and environmental performance in both operations and product design. The study will take experiences gained in other sectors, in particular electronics, translate them into a format suitable for the textile and clothing sector, and make the results widely available. Pilot activities in individual companies will demonstrate the benefits of this approach and form the basis of a 'club' process for wider dissemination and use.

Project aims

The main objectives of this project are:

1. to establish a process model for implementing Concurrent Product Development (CPD) with Design for Environment (DfE) in the textiles and clothing sector;
2. to evaluate existing tools and to specify appropriate tools for assisting the implementation of CPD with DfE;
3. to produce case studies of implementation demonstrating measurable improvements;
4. to disseminate the results through conferences, seminars, workshops and published material, providing the sector with practical guidance on implementation; and
5. to establish a framework for continuing activities designed to assist additional companies to successfully implement the process model.

The project team

This project benefits from having the collaboration of a number of the UK's leading companies in the textiles and clothing sector, as well as two universities with different and complementary expertise. The two collaborating universities, Manchester Metropolitan University and Cranfield University, include researchers who are experts in their fields. Manchester Metropolitan University have expertise in team working in the clothing manufacturing sector, and, textiles and the environment. Cranfield University has expertise in both Concurrent Product Development as well as Design for Environment in other industrial sectors.

CONVENTIONAL APPROACHES TO THE PRODUCT DEVELOPMENT PROCESS: INDICATORS OF CONTEMPORARY WEAKNESSES

Conventional approaches to product development in the textile and clothing industry have been characterised by functional independence. Each participant contributes to the process sequentially which results in excessive costs and rework in production associated with late stage design changes.

A recent apparel supply chain benchmarking study [2] highlighted product development lead times as a weakness in the UK's international competitive position:

"One area we have highlighted is product availability - both from supplier to retailer and from retailer to consumer. While compared with overseas competitors UK manufacturers' production lead times were the shortest, this was counterbalanced by the fact that developing the product in the first place is not as effective as international competition."

Efficiency of the product development process was also found to be low. On average, only 30 per cent of products developed actually find their way into the store, with designs often being changed more than four times from first sample to final approval.

In the following sub-sections some weaknesses of present procedures are reviewed.

1. Inadequate product development

In production departments, there tends to be a strong emphasis on operator productivity. Many resources are devoted to its measurement and considerable attention is paid to the results. However, many product start-ups are extended because of the inadequate resourcing of product development and process planning. For example, many initial ideas on assembly are based on sample room procedures rather than on factory-based production. These ideas will generally be communicated to the sales function, because this is where communication takes place with the customer over the details of the product. At a later stage, production people review the style - and sometimes with only a paper sketch, not a sample garment. Changes introduced at this stage to improve manufacturability create problems, as the specification with the customer has already been agreed. Companies producing for large retail chains find that the customer sometimes requires last minute changes to the product, leading to disruption of the product launch and problem solving during manufacture. Although Concurrent Product Development will not stop the customer making late changes, it does provide a framework for the improved management of the situation.

2. Design/production/marketing relationships

"Sealed samples" or their equivalent are often handed to the Production Department when the time comes to initiate assembly. This is equivalent to the Design Department "tossing the product over the wall" - a familiar illustration in Concurrent Product Development circles of communication weaknesses within a company. Issues of manufacturability are addressed at a very late stage, and the early stages of production are often characterised by related technical problems. One consequence has been the development of a "blame culture" within organisations, and difficult working relationships. Pogson [3] comments:

"Most present-day clothing designers, when asked to define their role in the manufacturing process, would probably stress the creative side as being the prime raison-d'etre. Indeed, it is true that without the accent on creativity the design function would soon become a technological offshoot of the manufacturing process, devoid of any artistic or marketing emphasis. Design, however, is an area which can be so all-embracing in its effects on the overall strategy of the business that it can seriously compromise performance, both financial and technical, in a manner which is not always apparent to senior management. The design function deserves to be examined critically, and in detail, in order to elevate it to its rightful status as a vital part of the engine which drives the business."

3. Geographical separation

Many designers work away from production facilities, and opportunities to interact are limited. With the trend towards offshore sourcing, the situation is getting worse and is likely to further aggravate the product development problem. As a consequence, within the present organisational structures, more "interface" people are likely to be appointed to resolve problems, check quality - and add to manufacturing overheads. Companies have responded to these indicators of weakness in a variety of ways. Two of the strategies which have been explored are identified below.

a. The greater use of garment technologists

Some companies have sought to provide more resources for product development by employing garment technologists. There is no doubt that these people contribute significantly to the launching of new products - but only a proportion of the problems can be solved because restrictions are imposed by the organisational structure. The source of the problems remains. Decisions made by other people may not be discussed and they may be non-negotiable. Just as Quality Circles cannot thrive without operator empowerment, so also pre-production garment technologists cannot achieve their full potential without Concurrent Engineering.

b. The employment of technologically-alert designers

To address the product development problems, there is a case for developing designers who are technologically alert. Pogson states in this respect [3]:

"Of course, garments cannot simply be designed around the skills of the workforce. And whilst it is true that many changes are in answer to market forces, there are many others which, upon investigation, prove to be ill-advised and unnecessary. This poses the question as to whether designers should be practical technicians in the sense of having a thorough knowledge of the manufacturing process, for it is only by knowing the effect that small and apparently insignificant changes may have on the plant's efficiency that a proper appraisal can be made,".

Whilst this is certainly desirable, unless the organisational structure changes, the benefits are restricted. This is because designers do not have good feedback loops or communication channels to develop and enhance their technical skills. Furthermore, one wonders how realistic it is to expect designers to develop a maturity in technical competence. Is it fair to expect one person to have all the skills? The smaller the variability in the product range, the easier it will be.

These two strategies are, at best, part solutions. They help within existing organisational structures, but the potential is present for a more radical approach to the problems.

Reducing lead times in design and development

The product development process can be likened to a relay race, where a baton (the product) is carried by a succession of runners from the start (design concept) to the finish (in the hands of a satisfied customer) in the shortest possible time. Transfers of the baton from one runner to the next must be handled well so that there are no false moves and no delays. The analogy starts to look more complex when we think about who the runners are, and how the baton is passed from stage to stage.

Each leg of the relay race has a name: "product concept", "design sample", "customer-approved sample", etc, as in the accompanying illustration. In each case, groups of people are responsible for completing each leg. Within traditional company structures, there are problems: employees have only a limited understanding of their contribution to the product development process. In particular, there are weaknesses in relating their work to that of others, and of running to win the race rather than merely being a participant in their specific leg. As a result, the transfer of the baton is not performed well.

It is, of course, widely recognised that this complex process can be analysed and controlled. The danger is that the control system has an adverse effect on the timescales of the whole process, especially if the baton changes are specified to require the total completion of one task before starting the next as illustrated in Figure 1 overleaf as the "Conventional route."

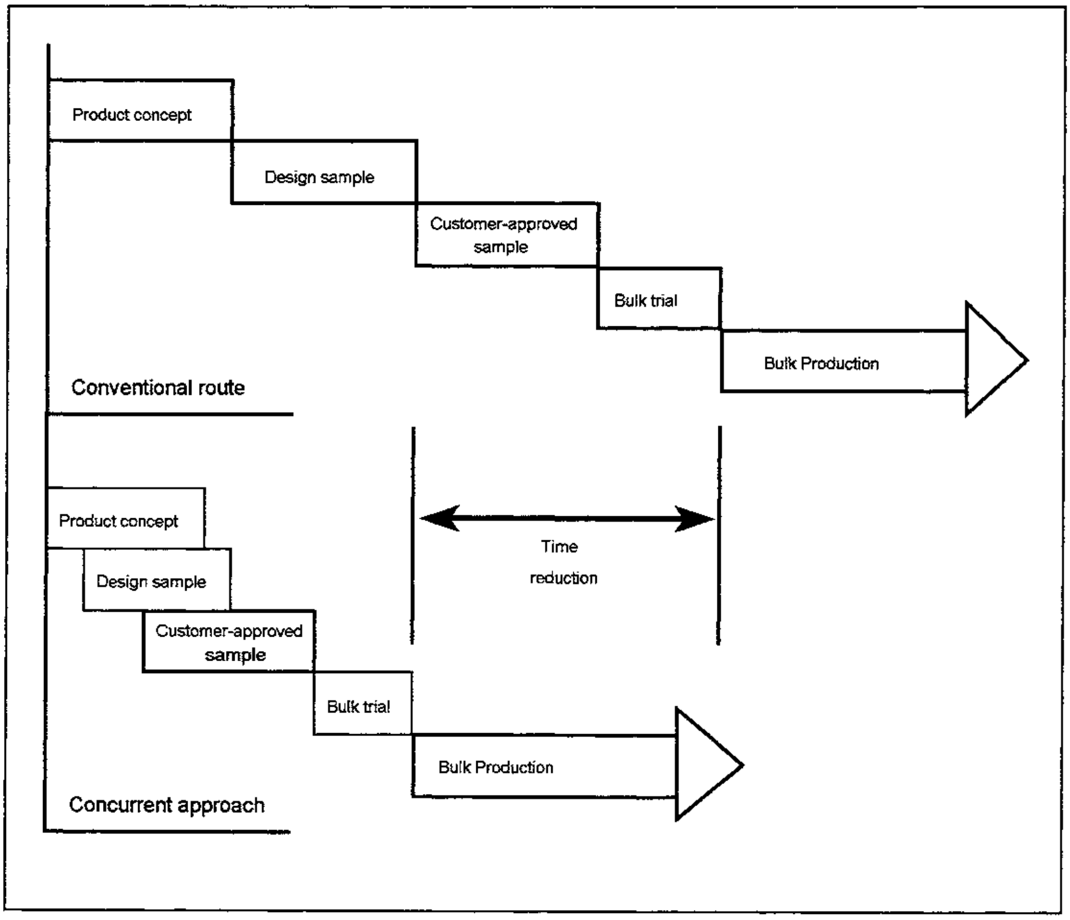

Figure 1: Conventional route to product development

In traditional organisations, design teams believe they know what their customers want. They produce sample garments and ranges - only to find that they have not got things quite right, see Figure 2. The result is a series of late-stage product changes which are time-consuming and costly. The adoption of formal methods within the framework of Concurrent Product Development has customer orientation as the target. This entails establishing better communications with customers, questioning presuppositions, reducing unproductive debate, and generally providing a sharper focus for all activities. This is discussed in detail in the following section.

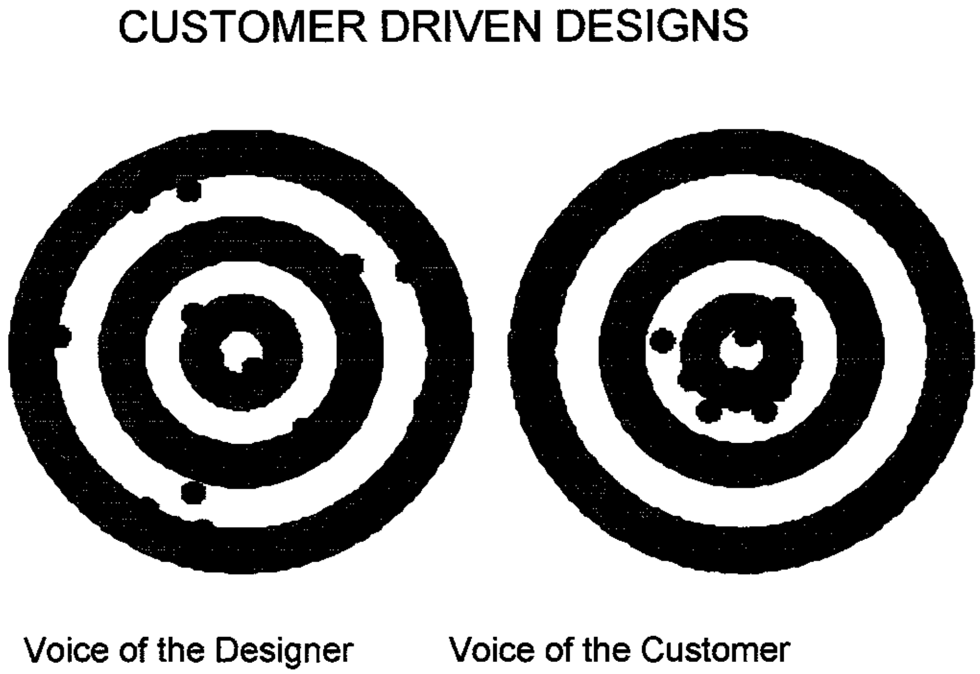

Figure 2: Customer-driven designs

TEAMWORKING IN THE PRODUCT DEVELOPMENT PROCESS

This project is concerned with novel approaches to the product development activity, particularly Concurrent Product Development and Design for Environment. The driving principle of Concurrent Product Development is to deliver better, cheaper, faster products to eliminate waste: and to improve communication throughout the product development process. This is achieved through the use of multi-disciplinary teams from the beginning of a design project and planning and investment in early design activities. Extra time and effort spent in the early phases of design reduces the need for costly and time consuming design changes, and lessens the chance of product recall. Teamworking within organisations can also unify the work of people with very different backgrounds, technical discipline, experience, and organisational responsibilities. Although it is widely recognised that this diversity of team members also represents significant challenges in maintaining effective communication.

Benefits

CPD has been used in other sectors for a number of years and has delivered measurable benefits, and there is a strong case for some sector specific technology transfer. A survey of 19 companies who implemented concurrent engineering (CE), or what we term concurrent product development, in their design processes, conducted by Cranfield University, indicated on average a 90% improvement in quality, a 25%

improvement in cost and a 70% improvement in time. The information in Table 1 overleaf illustrates the quality, cost and time improvements experienced by five large companies who have implemented CPD strategies:

Table 1: Improvements after CPD Implementation. Source: Cranfield University.

	Cost Reduction	Time Reduction	Defect Reduction	Parts Reduction
AT&T (Electronics Sector)	88%	46%	30%	33%
McDonnell Douglas (Defence Sector)	60% life cycle 40% production		58%	
Digital (Electronics Sector)	50%	50%		
Honeywell (Electronics Sector)	$11.1 million saved in 3 years	30%	97.6% products defect free	
General Dynamics (Electronics Sector)		50% in design 72% in assembly		

Components of concurrent product development

Concurrent product development typically has four components in its implementation which can be categorised as 'hard' and 'soft' and these cover the whole of the product development process. This is illustrated in Figure 3 below.

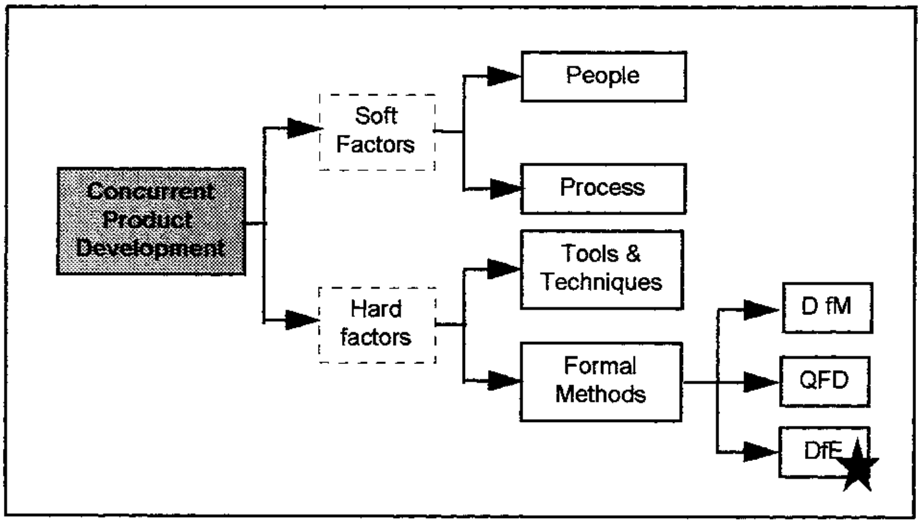

Figure 3: Concurrent Product Development

The soft components are the people and processes. Both the people and the process are to be included in the process model resulting from this project. The hard components are the tools and the formal methods. Formal methods include Design for Manufacture (DfM), Quality Function Deployment (QFD) and Design for Environment (DfE). In the first stage of implementation, it is not proposed to implement all possible formal methods. For this project, Design for Environment has been selected to facilitate the implementation of Concurrent Product Development.

Design for Environment (DfE) has been recognised in the electronics sector for a number of years as being essential if they are to compete in a global market place where governments are regulating against pollution and environmental damage. As the pace of demand for products and processes with environmental sensitivity increases, it is recognised that high levels of environmental awareness and expertise will be required for product development in the future, offering new opportunities for competition and new environmentally sensitive products to enter the market. As the industry continues to strive for improved environmental performance this is the next step forward, moving from 'end-of-pipe' solutions towards developing 'cleaner products' with minimal environmental damage. As industry adopts team working methods and systems, environmental factors must also become an important future consideration in new product development. If multi-disciplinary teams are targeted with tasks to reduce the organisations environmental impact on both a 'process' and a 'product' level, this effectively ensures ownership of the problem and ensures greater success in implementation.

CONCLUSIONS

The overall objective of this project is to greatly improve the competitiveness of the UK textiles and clothing sector, enabling the sector to move towards improved standards of quality, innovation and environmental performance in both operations and product design. It is anticipated that the input of this work will be to increase operational measures, for example customer satisfaction, the rate of product innovation and the environmental performance of the collaborating companies.

This approach has a number of merits, firstly, by learning from the experience of other sectors the textile sector may be able to shorten their learning curve. Our collaborating companies have been chosen from different stages of the textiles and clothing supply chain from raw material (chemicals), through dyeing and finishing, fibre production, garment manufacture and retailing. We feel this will give us a unique insight into the different types of processes that are used in new product development and ensure that our results are adaptable to any part of the sector.

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INNOVATIVE KNITTED STRUCTURES FROM WASTE MATERIAL

Hilmar Fuchs, Rolf Arnold, Monika Seeger, Anna-Maria Bartl and Evelin Hufnagl

INTRODUCTION

A basic problem of today's European textile industry is to find new fields of product application. Another important question industrial countries are faced with is waste material. Our Institute has worked in the field of technical textiles for decades and developed several technologies and products which provide solutions.

TYPES OF INDUSTRIAL TEXTILE WASTE

Large quantities of textile waste accumulate in companies during the manufacture of knitted, woven and nonwoven fabrics, coated products etc. This waste is usually unsoiled and may be found in shapes of strips, flocks or fibres.

An extensive analysis, in co-operation with several German national associations and approximately 200 companies producing a wide variety of products, was carried out. An amount of about 48,000 t of textile production waste per year was determined. The waste material accumulates in the form of edge clippings, cut pieces of fabrics or strips of fabrics as well as waste of different shapes and sizes such as flocks, chips, cropping waste and bulk goods.

The basic problem when processing industrial textile waste is connected with feeding the material into the processing unit. To reduce the volume of waste, narrow fabrics and strips of fabric waste are usually wound onto rolls and bobbins in order to separate the waste during the production process. However, the edges of woven and nonwoven fabrics are usually tangled. After cutting, the edges are stored in barrels or suitable containers and then compressed into bales. Flocks, cropping waste, small pieces of fabrics are immediately extracted during the finishing or production process and then compressed into bales. Because of their large quantity and particularly their bulky shape, clippings, piece-good waste and edge waste from high-tenacity coated fabrics are cut into small pieces to reduce volume when deposited in landfill sites.

PROCESSING TEXTILE WASTE MATERIAL ON KNITTING MACHINES

The manufacturing of rope-like structures

In the Saxon Textile Research Institute in Chemnitz /Germany, research work has been carried out processing different types of textile waste by using stitch forming technologies such as warp and weft knitting (circular and flat) and a special technology called KEMAFIL, in which stitch forming loopers are used instead of needles. The product has a rope-like shape with courses running in a lengthwise direction.

When using other circular knitting technologies, the knocking-over forces act longitudinally, not as on the KEMAFIL-machine radially. This results in soft and voluminous ropes. During the KEMAFIL-process the radially acting lacing forces are particularly suitable for wrapping the filling material, which is fed into the centre of the compact rope. Depending on the number of stitches per inch and the yarn tension, an extremely wide range of rope structures can be manufactured. The filling material can be

flocking (waste wool or cotton etc.),
chips, a mixture of clippings etc.,
edge strips and other similarly shaped material.

In addition to this synthetic and non-synthetic waste, it is even possible to feed non-textile materials such as perforated tubes into the centre of the rope and wrap them with layers of nonwoven. By selecting suitable components of the material, a wide variety of ropes can be produced which vary in volume, porosity, absorbency, water transport performance, compressibility and tenacity.

To manufacture these structures, the appropriate feeding and winding-up attachments have been developed. The range of diameters of KEMAFIL structures is very wide, and diameters up to 130 mm (more than 5 inches) are possible .

The manufacturing of matting- and lattice-like structures

Coarse warp knitted mats

When using standard latch or compound needles, textile waste material can be primarily processed by way of weft insertion. Depending on the structure of the recycled material, a preliminary compression is required to process it in a trouble-free manner. For this compression the KEMAFIL-technology can be used.

Such extremely coarse "yarns" of diameters up to 14 mm have been inserted at needle distances between 10 – 25 mm as fillers (vertical inlay), warp inlays 0-0/1-1// or as a combination of weft and warp insertions.

Soft edge strips, such as those originating from nonwoven productions, of up to 8 mm in diameter were fed directly into guide tubes and processed on an extremely coarse warp knitting machine to produce voluminous lattice structures. This double needle bar warp knitting machine was developed by our Institute. It is provided with outsize latch needles and two independently controllable weft insertion attachments. On the basis of this machine, the Jakob Müller AG in Frick, Switzerland, succeeded in developing and launching a completely new coarse warp knitting machine at ITMA '95. The new drive and control concept allows a highly efficient production of previously impossible structures.

Due to the use of extremely coarse knitting elements and suitable feeding attachments, it was possible to process "yarns" of the following diameter ranges:

Ground yarn:	up to approximately 8 mm
Warp insertion:	
(filler and sectional weft inlay 0-0/1-1//):	up to approximately 14 mm
Weft insertion:	
• flexible material	up to approximately 25 mm
• stiff material (rods, tubes)	up to approximately 20 mm

Depending on the flexibility, the deformation behaviour and the required characteristics such as porosity, absorbency, tenacity and packing density, the waste material (edges) was processed directly or in the form of KEMAFIl-ropes made from waste in the form of strips or loose waste.

Stitch-bonded fabrics

An alternate way of processing rope-like structures from waste material is stitch-bonding. A modification of the knitting zone, particularly of the knocking-over edge which is in sections, made it possible to integrate stiff ropes from waste materials into composite fabrics. These ropes were inserted as fillers and covered with additional layers of nonwoven or woven fabrics . The fillers in the drainage mat are KEMAFIL-ropes of low compressibility made from coated woven fabrics alternating with porous KEMAFIL-structures knitted from 5 mm wide plastic strips as looper yarns. The thickness of these stitch bonded fabrics is up to 20 mm.

On the same type of machine a lattice-like structure can be manufactured The meander-like weft-insertion can be made from different types of waste material, for instance from KEMAFIL-ropes made from coated edge strips similar to those used for drainage mats. Alternately, the waste edge strips can be inserted directly as weft material.

APPLICATIONS

An important part of our research and development have been practical tests. There are many fields of application of rope-like structures and mats. One of the most important is the use as drainage elements (Table 1).

Table 1: Rope-like structures and mats for drainage purposes, fields of application

Fields of application	**Examples**
Building and civil engineering	• Construction of housing and public buildings (foundations, walls) • Railway constructions • Road building • Civil engineering (e.g. tunnel construction, dams, channels)
Horticulture	• protection against erosion (embankments) • melioration / drainage • basins for collecting water • green areas
Environment	• construction of landfill sites: storage and waste disposal of liquid and solid waste

In practical trials for rope-like structures, tests have been successful for amounts of water of 0.5 l per second and hectare (10,000 m^2) in:

(i) temporary drainage systems for building sites and excavations
(ii) permanent drainage of wet areas of cultivated land, open spaces and parks, allotments, greenhouses and of supporting walls and embankments
(iii) water derivation of rainwater and treated sewage
(iv) filling elements of mole drainage, derivation of water seepage

A core of a longitudinally oriented structure made from elastic plastic waste is wrapped by an additional filter layer and a cover for water storage.

Drainage mats have several advantages:

- they are flexible and durable and do not break

- the compact structures protect against impacts
- the inserted ropes cause a high tenacity in a longitudinal direction
- high water transmissivity (ability to transport water)
- in combination with a film, they protect against water or block it
- they can be combined with filter layers of a wide variety of pore sizes
- It is not necessary to use layers of gravel and soil which has been dug out and the dug out soil is suitable for re-use

In one example of a built-in drainage mat, the two different types of drainage ropes between two geotextile filter materials serve both for drainage and stability against compression. The results of measurements have shown that the transmissivity of drainage mats developed by our Institute is well within the area of commercial products .

A further application is the reinforcement of concrete, for instance by ropes inserted in plates used in hydraulic engineering and built into an outlet channel as a reinforcement for safety in transportation.

Very thick KEMAFIL-ropes filled with waste wool or even hay have been used for thermo-insulation, for instance in an ecological house.

Irrigation applications

The ropes and mats suitable for drainage can also be used for irrigation. To irrigate trees or other plants which grow in sealed areas (pavements, roads etc.), water can be passed forward by means of ropes towards the roots. in our experiments a perforated tube in the core was wrapped with nonwoven waste strips. The supply of water can be varied by the diameter of the tube and the perforation. To give an example, 0.2...0.5 l/h·m has been achieved at 0.1 bar and a nominal diameter of 10 mm. These irrigation ropes are mainly used to supply water directly to the root area of the plants. Since there is no evaporation and loss of water seeping away, a very efficient and economical irrigation is possible.

Oxygenation and aeration

In order to preserve or restore the biological and material equilibrium, artificial ventilation and oxygenation are used in reservoirs, in stretches of water and for the treatment of sewage and slurry. In addition, it serves the purpose of securing the oxygen balance for the preservation of the fish stock and the self-purification of the water. When aerating deep water, the mixing of the thermal layers in the water must be avoided. This is possible by using textile layers with small openings. A perforated synthetic tube is wrapped in textile layers from waste material. As a result, very small bubbles are evenly distributed in the circumference of the tube and a highly effective oxygenation is possible without any considerable upward movement of the water. A further area of application is keeping sections of water ice-free.

The wrapping layer of the rope-like structure for oxygenation is produced primarily from low-cost textile waste like strips, fringes, loose material, etc.

Trials for practical testing have shown, that amongst other things, the even homogeneous and relatively closely packed wrapping will create favourable effects when used for aerating purposes. Oxygen enrichments such as needed in fishponds and fish-farms can be effected without difficulty by means of the new structures.

Horticulture and agriculture

In Germany, there is a special levy on water when areas are sealed, for instance roofs. When these areas are covered with plants, it is possible to save on some of these costs. Furthermore, roof planting helps to create better environmental conditions in cities and industrial areas.

A wide variety of well functioning systems of roof planting are on offer. However, they have relatively complicated, multi-layered structures. With a weight of up to 120 kg/m^2, they are often too great a load for many buildings. By developing thick, mat-shaped textile structures, it is possible to cultivate reposition plants without soil. This provides a new variation of green areas on concrete, roofs and embankments.

For example, the roof of a factory hall in the city of Mannheim has been covered with textile mats with special plants on it. The roots have developed very well on these mats used for roof planting, floating islands, for concrete basins and the treatment of sewage.

Modern methods for growing ornamental plants and vegetables in greenhouses do not involve the use of soil, but instead drip-water-systems. The hydro-culture and nourishment-enrichment film technologies have been developed and rock-wool has been used as well. To an increasing extent rock-wool has caused disposal problems. In Belgium and Holland, the cultivation without soil has become very important. The various types of plants grow very well on standard substrates and it is possible to control the cultivation of plants and root developments by means of a computer. Further developments in the field of nourishment-enrichment-film technology for under-glass cultivation have brought about investigations into polyurethane foam-backing waste, wood chips and backing fabric as basic materials for plant supports. By using these materials the disadvantages of rock-wool should be compensated, avoiding high energy consumption in production and problems occurring in recycling.

The rope-like materials which have been developed by our Institute were tested with good results by a number of horticultural institutions when cultivating tomatoes, pepper, zucchini and melons, as well as roses, chrysanthemums and pelargoniums. The trials were carried out using a variety of recycled materials. Our tests have shown that the recycled substrate causes the same good results as conventional substrates like hydro-clay and rock-wool.

The various tests under practical user conditions were evaluated under such headings as the loss of plants, the number of leaves, or the harvesting results. As far as the later composting of the plantbeddings together with the plant residues is concerned, very favourable results of the rotting material have been recorded. Synthetic recycling material particularly for long term cultivation or re-use is very much to be recommended.

CONCLUSIONS

As our results show, a modification of knitting technology in combination with the use of very extreme materials offers completely new types of knitted fabrics for use in building, civil and hydraulic engineering as well as in agriculture and horticulture. The more successful the adaptation of the new structures to product requirements the greater is the rate of success in the market. This requires the closest co-operation of research institutions and fabric manufactures able to take risks, as well as progressively minded users of the product.

Acknowledgement

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NOVEL VEGETABLE FIBRE GEOTEXTILE STRUCTURES FOR SOIL REINFORCEMENT

M. Pritchard, S.C. Anand and R.W. Sarsby

INTRODUCTION

Geotextiles are fabrics, woven, nonwoven, knitted, knotted and grid structures, which are used in intimate association with earth material. They are normally of synthetic origin, either regenerated cellulose or from petroleum products, thus they often have a long-life. However, in many ground engineering situations e.g. temporary roads over soft land, basal embankment reinforcement, geotextiles are only required to function for a limited time period. Furthermore conventional geotextiles are usually prohibitively expensive for developing countries. Many of these countries have abundant supplies of cheap, indigenous, natural fibres such as jute, sisal and coir and textile industries capable of replicating common geotextile forms.

Table 1: Functional requirements for reinforcing geotextiles

Properties required		Properties required	
Tensile strength	iii	Creep	iii
Elongation	iii	Permeability	na-i
Chemical resistance	ii-iii	Resistance to flow	i
Biodegradability	iii	Properties of soil	iii
Flexibility	i	Water	iii
Friction properties	iii	Burial	iii
Interlock	iii	UV light	ii
Tear resistance	i	Climate	na
Penetration	i	QA & control	iii
Puncture resistance	i	Costs	iii

iii = Highly important
ii = Important
i = Moderately important
na = Not applicable

PROPERTIES

Geotextiles have several functions: reinforcing, separation, filtration, drainage and erosion control, which can be performed individually or simultaneously, but this versatility relies upon the structure, physical, mechanical and hydraulic properties of the geotextile. The emphasis of the use of geotextiles in this paper is on short-term reinforcing applications. The general properties required to perform this function are detailed in Table 1. Figure 1 illustrates the stress/strain properties of various vegetable fibre yarns. The stress/strain properties of other well known yarns are illustrated in Figure 2 for comparison. It can be noted that, in general vegetable fibre yarns have high strength, modulus with low elongation and elasticity, these properties make them ideal to form reinforcing geotextiles.

APPLICATIONS

A typical example where a geotextile can be employed as a reinforcing element for a short-term application is underneath an embankment which is termed 'Basal Reinforcement'. The use of a geotextile when constructing an embankment over soft, compressible ground presents an invaluable solution. The load from the embankment fill, during or just proceeding the construction, may cause the embankment to fail. Figure 3 illustrates three typical modes of failure which may be encountered, as a result of the

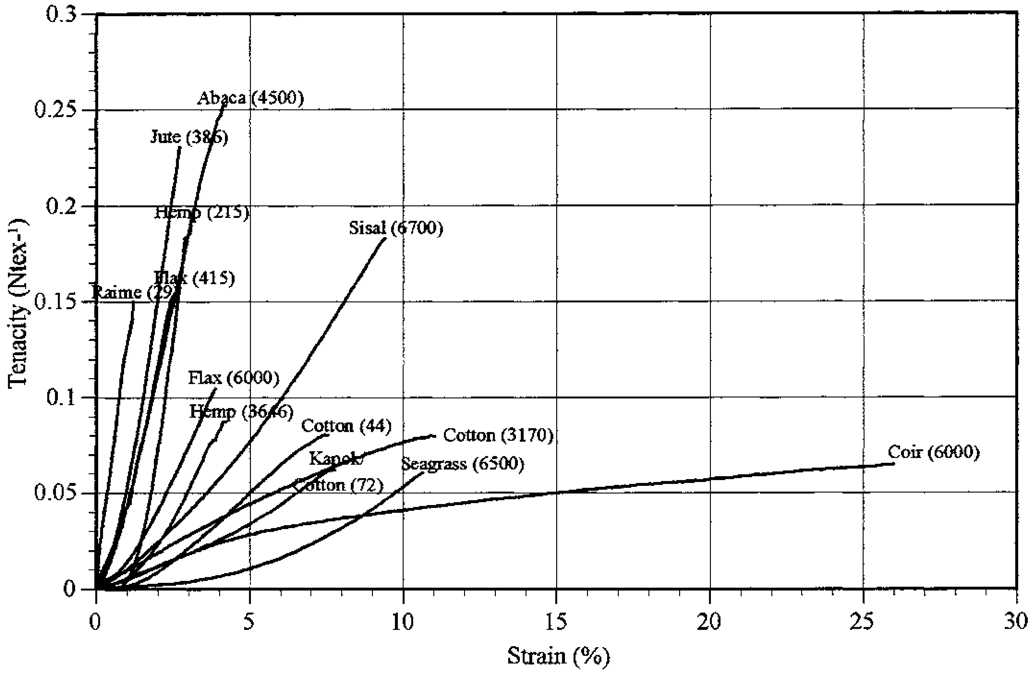


Figure 1: Stress/Strain properties of various vegeatble fibre yarns

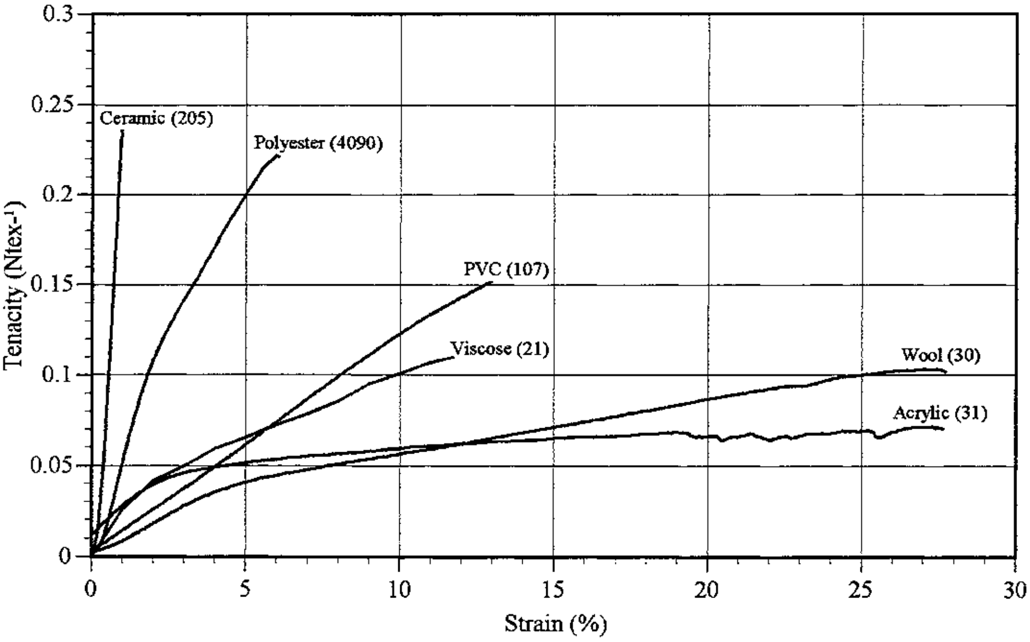


Figure 2: Stress/Strain properties of various well known yarns

N.B. The number in the bracket indicates the tex value for that particular yarn

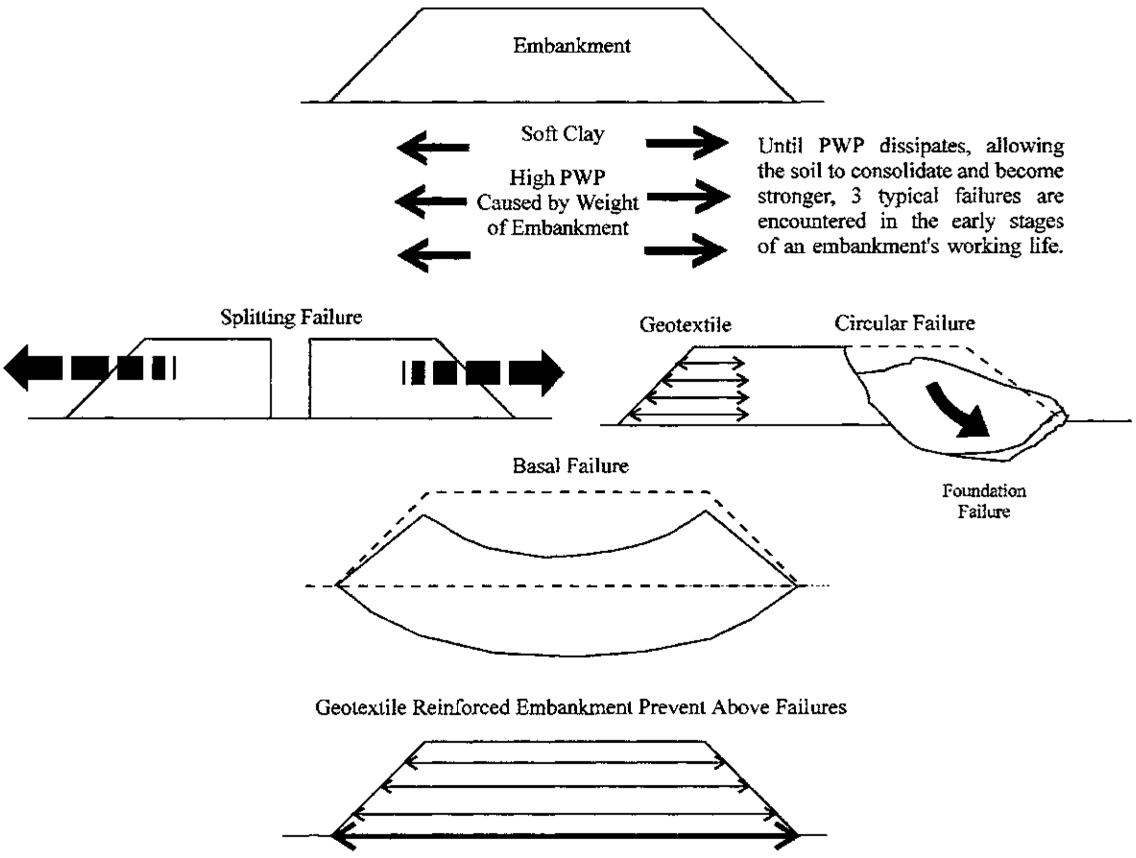


Figure 3: Short-term applications for geotextiles in embankments

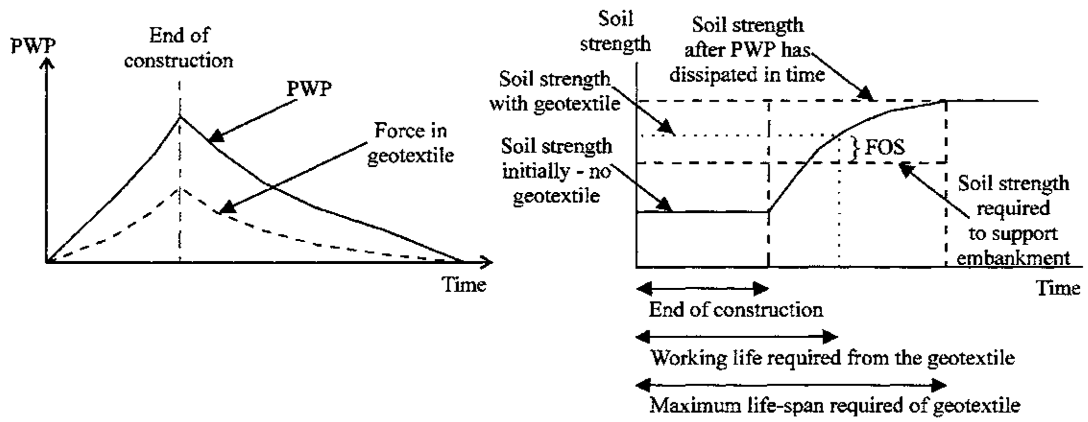


Figure 4: Stabilising force to be provided by the geotextile will diminish with time

underlying soft soil not having sufficient strength to resist the applied shear stresses. The use of geotextiles at vertical increments in a embankment and/or at the bottom of the embankment, between the underlying soft soil and embankment fill, would provide extra lateral forces which either prevents the embankment from splitting or introduces a moment to resist rotation. Stability of the embankment will improve in time (1 to 2 years) as the excess pore water pressure from the underlying soft soil dissipates, hence its strength will increase and the stabilising force provided by the geotextile will diminish with time as shown in Figure 4. This decrease, in the required stabilising force, can be designed in parallel to the rate of deterioration of the natural fibre geotextile.

NOVEL GEOTEXTILE STRUCTURAL FORMS

Table 2 indicates the eleven different types of geotextile structures which are under laboratory evaluation together with their respective tensile strengths, strains and standard properties. The stress/strain graphs are also given in Figure 5, the curves shown are for the fabric in both the strength and cross-strength direction. Numbers 1 to 5 of these structures have been designed, developed and produced in the Textile Centre at Bolton Institute from novel structure runs with the selected natural fibres, namely coir, sisal and flax, to enable the creation of the most suitable compositions of fabrics, their forms being weft knitted inlay and woven structures. Numbers 6 to 11 are all commercially available geotextile products, with 6 to 9 being of a natural fibre origin. The coir knotted geotextile was chosen to consider the effect of larger particle interlock with the fabric and large abutments formed by the knots. This geotextile was obtained from India (Aspinwall & Co. Ltd.) where the knots are produced by hand. The nonwoven samples were obtained from Thulica AB, Sweden, for a comparison with the knitted and woven natural fibre structures. However, geotextiles 10 and 11 are of a synthetic origin from the midrange of synthetic products commercially available. These were used for a direct comparison with the natural fibre geotextiles using exactly the same tests and procedures.

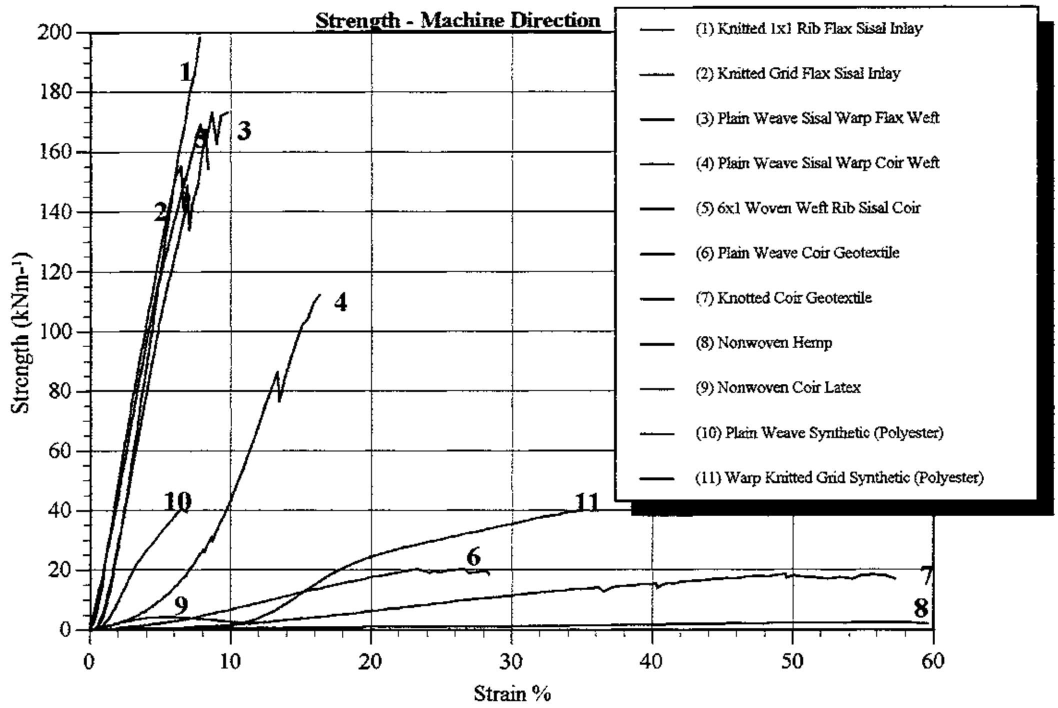
The first five fabrics have been created with the fundamental properties required to form geotextiles to reinforce soil, in that they have been designed to provide:-

1) The highest possible strength in one direction together with low elongation - combined with the ease of handling and laying on site; this was obtained by having the highest number of straight high strength inlay yarns in one direction as possible, with the fabric skeleton structure, made from thinner more flexible weaker/cheaper yarns, holding the inlay yarns in place.
2) Soil particle interlock with the fabric to such an extent that the soil/fabric interface exhibits greater shearing resistance than the surrounding soil i.e. the soil/fabric coefficient of interaction ($\propto$) is greater than one; abutments and apertures in the geotextiles were created to produce this high shear resistance.
3) A degree of protection to the high strength yarns; this was achieved by encapsulating the high strength yarns by a sacrificial structure formed from cheaper more degradable yarns, this factor reduces the effect of introducing a large reduction factor into the design to account for installation damage from certain types of fill/plant.
4) Ease of manufacture on conventional textile machines; the aim was to use existing textile machines with slight modification to produce novel structures made from vegetable fibres rather than making a complete new machine - this in turn will keep the costs low and enable the vegetable fibre geotextiles to be mass produced very quickly.

Numbers 1 and 2 are the most novel structures developed, being of a weft knitted origin. The knitted loops being formed from a flax yarn (tex $\approx$ 400) encapsulating high strength sisal yarns (tex $\approx$ 6,700) which can be inlayed both vertical and horizontal (machine and x-machine direction). The knitted flax and inlay sisal yarns can be substituted by other natural fibres yarns. The knitted flax/sisal inlay number 1 has as many straight inlay yarns as possible in one direction which gives the geotextile its high strength, without introducing crimp into these yarns hence producing a fabric which has

Table 2: Standard properties of vegetable fibres and commercially available geotextiles

	Average of 5 fabric samples for all test results shown	Disp. at max. load (mm)	Load at max. (kN)	Strain at max. load (%)	Stress at max. load (Nmm^{-2})	Load/Width at max. load (kNm^{-1})	Modulus (Nmm^{-2})	Toughness (Nmm^{-2})	Mass (gm^{-2})	Thickness @ weight 100g (mm)
1	Knitted flax sisal inlay (strength direction)	16.35	10.33	8.18	57.39	206.60	878.80	3.85	1753.23	5.3
	Knitted flax sisal inlay (x-strength direction)	80.04	1.03	40.02	3.74	20.57	9.59	0.50		
2	Knitted grid flax sisal (strength direction)	14.88	7.88	7.44	32.63	143.58	601.60	3.88	1613.81	4.4
	Knitted grid flax sisal (x-strength direction)	97.76	1.09	48.88	4.35	19.15	19.15	0.47		
3	Plain weave sisal warp flax weft (warp direction)	19.28	8.99	9.64	49.94	179.80	723.40	4.34	1289.95	3.6
	Plain weave sisal warp flax weft (weft direction)	58.07	0.22	29.04	1.22	4.40	0.27	0.06		
4	Plain weave sisal warp coir weft (warp direction)	32.68	5.65	16.34	14.86	113.00	89.90	1.59	1895.48	7.6
	Plain weave sisal warp coir weft (weft direction)	51.70	1.32	25.85	3.48	26.42	33.78	0.73		
5	6x1 woven weft rib sisal warp coir weft (warp direction)	16.69	8.53	8.35	14.10	170.60	243.60	0.96	3051.75	12.1
	6x1 woven weft rib sisal warp coir weft (weft direction)	68.16	5.58	34.08	9.23	111.70	58.70	2.87		
6	Plain weave coir geotextile (warp direction)	56.23	0.99	28.12	2.47	19.74	14.32	0.50	1110.99	8.0
	Plain weave coir geotextile (weft direction)	44.01	0.89	22.00	2.23	17.86	17.80	0.41		
7	Knotted coir geotextile (long direction)	105.90	0.92	52.95	5.93	18.38	18.10	1.87	605.37	3.1
	Knotted coir geotextile (width direction)	389.60	0.33	194.80	2.12	6.56	4.13	0.90		
8	Nonwoven hemp (machine direction)	112.70	0.11	56.37	0.48	2.15	11.48	0.16	683.16	4.5
	Nonwoven Hemp (x-machine direction)	85.47	0.17	42.74	0.76	3.43	3.58	0.22		
9	Nonwoven coir latex (machine direction)	12.26	0.20	6.13	0.74	4.07	19.56	0.07	1018.24	5.5
	Nonwoven coir latex (x-machine direction)	11.18	0.15	5.59	0.54	2.95	13.10	0.05		
10	Plain weave synthetic polyester (warp direction)	16.35	2.07	8.17	51.62	41.30	960.90	2.94	432.09	0.8
	Plain weave synthetic polyester (weft direction)	19.62	2.30	9.81	57.50	46.00	836.70	3.52		
11	Synthetic warp knitted polyester (warp direction)	55.78	2.32	27.89	27.31	46.42	262.60	4.18	430.13	1.7
	Synthetic warp knitted polyester (weft direction)	102.87	0.11	51.43	1.31	2.23	41.55	0.26		



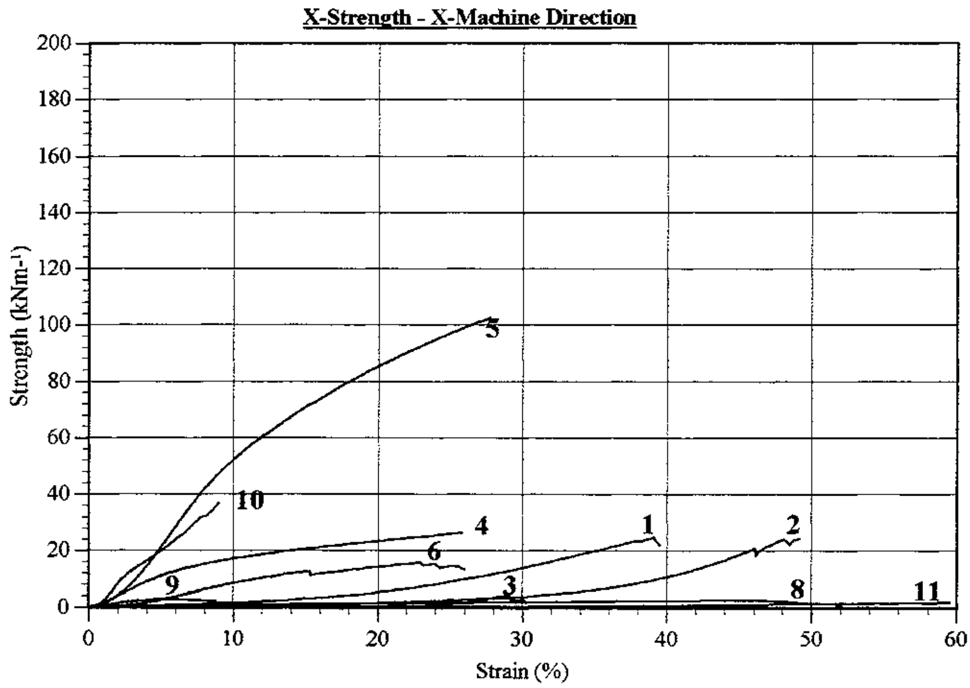


Figure 5: Stress/Strain graphs for vegetable fibres and commercially available geotextiles

N.B. The curves shown on the above graphs are the data points for one typical test only - the average results from the five samples tested are shown in Table 2. Curve 7 on x-strength graph has been omitted due to the scale range i.e. failure occurs at a strain of 195 % see Table 2.

low extensibility as compared to conventional woven structures. The knitted loops hold the inlay yarn in a parallel configuration during transportation and laying on site - under site conditions it would be impractical to lay numerous individual sisal yarns straight onto the ground. The knitted loops also provide some protection to the sisal inlay yarns during installation/back-filling. The most advantageous use of the knitted loops in this structure is that they form exactly the same surface on both sides of the fabric and the sand is in contact with not only the knitted loops but the inlay yarns as well. Thus the shear stress from the sand is transmitted directly to both the inlay yarns and the knitted skeleton. With the grid flax/sisal geotextile number 2, at predetermined intervals needles were omitted and the sisal inlay yarn left out, to produce large apertures in the geotextile. This is similar in form to the Tensar Geogrid, which allows large gravel particles to penetrate into the structure thereby 'locking' the gravel in this zone and forcing it to shear against the gravel above and below the geotextile, rather than just relying on the surface characteristics. One example of different structures developed in this research programme is shown in Figure 6.

FRICTIONAL RESISTANCE OF GEOTEXTILES

When subjected to a vertical stress, the soil in close proximity to the geotextile will encounter tensile incremental strain. This will result in the soil attempting to deform laterally with respect to the geotextile. This deformation can only be resisted if the bond between the soil and geotextile is sufficient to prevent slippage. The resistance offered by the fabric structure can be attributed to the surface roughness characteristics of the geotextile (soil sliding) and the ability of the soil to penetrate the fabric i.e. the aperture/abutment size of the geotextile in relation to the particle size of the soil (bond and bearing resistance). The shear strength behaviour of granular soils also has an important effect on the shearing resistance. This strength consists of an internal frictional resistance between soil particles shearing against other particles and the interlock between the soil grains which have to slide over one another (dilate).

Measurement of shearing interaction

The eleven geotextiles were tested in a 300 x 300 mm (plan dimensions) partially fixed direct shear box. The relative horizontal displacement of the two halves of the shear box, the change in sample height during shearing and the vertical displacement of the top four corners of the upper half of the shear box were monitored by linear dial gauges.
The tests were conducted with both dry Leighton Buzzard sand and limestone gravel (average particle diameter 0.8 mm and 6 mm respectively).

Nominal normal stresses of 200, 150, 100 and 50 kNm^{-2}, to represent the likely range of soil pressures which would apply to field situations, were applied to the samples.

The upper and lower halves of the shear box were compacted each in three layers of equal thickness using a vibrating hammer and tamping plate to a predetermined thickness to produce a nominal unit weight of 96 % and 94 % of the maximum nominal dry unit weight for the sand and gravel respectively. These figures were chosen to represent the density likely to be achieved on site, whilst maintaining an accuracy of $\pm$ 0.01 Mgm^{-3} from the mean dry density in subsequent shear box tests. The leading side of the bottom half of the shear box had the geotextile clamped to it.

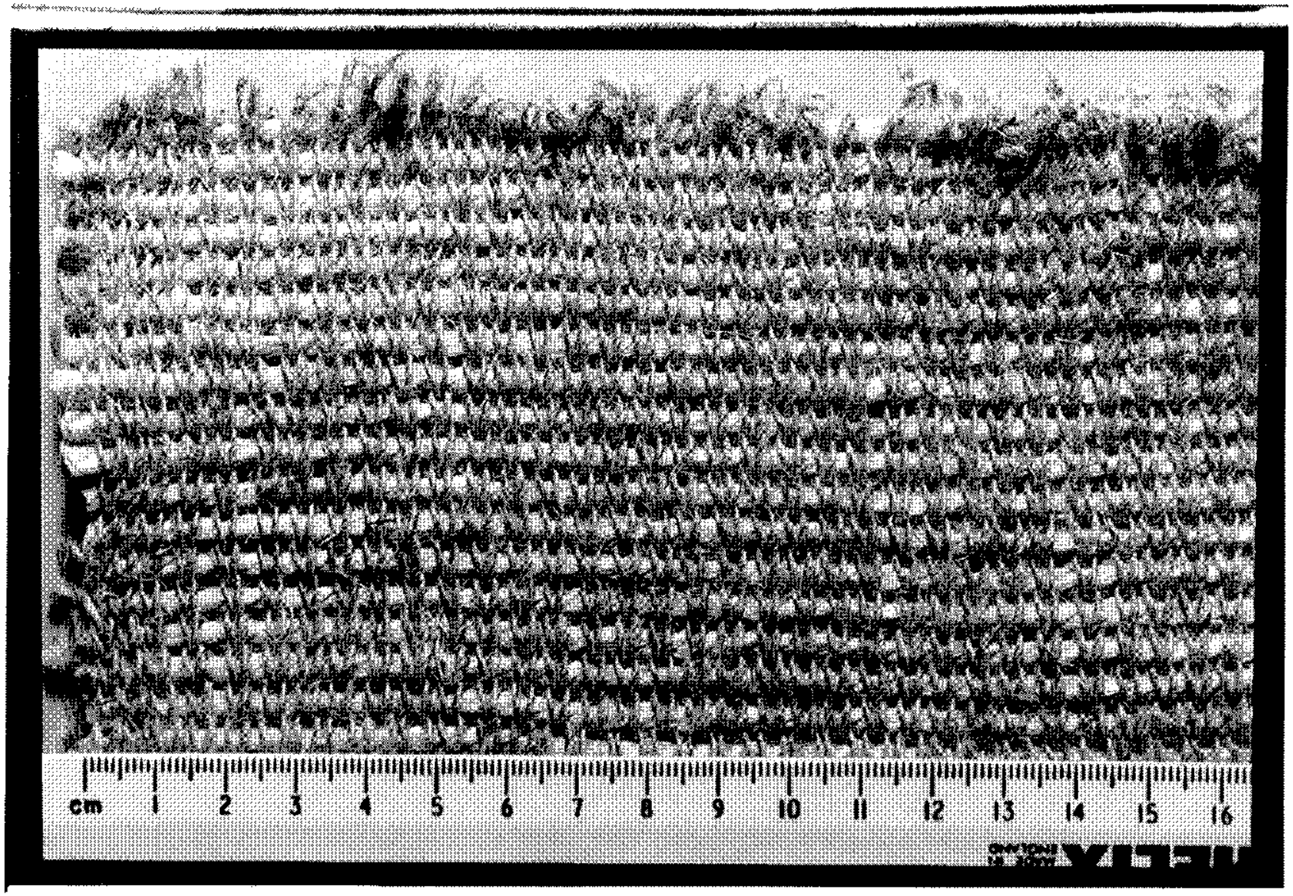


Figure 6: Natural fibre weft knitted directional structured (reference number 1) developed at Bolton Institute

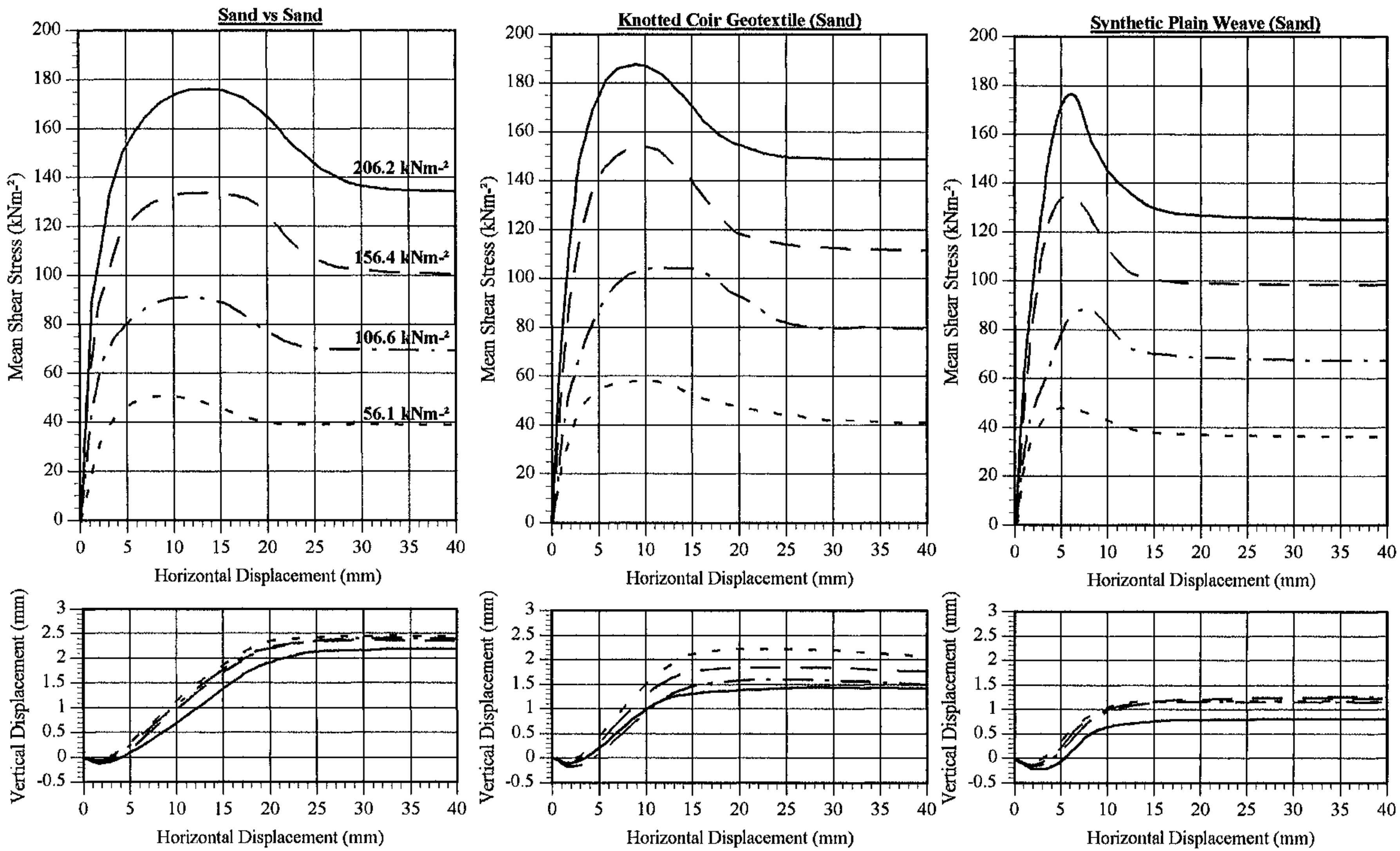


Figure 7: Typical shear box stress/strain and volumetric plots

Performance of the vegetable fibre geotextiles during shear

The stress-strain response and volumetric behaviour for all the geotextiles in both sand and gravel are typical of a densely packed granular dilating medium. Figure 7 illustrates typical plots. It can be noted that the knotted geotextile plots produce very similar plots to that of sand alone, indicating that the influence of the geotextile is minor. However, the stress/strain for the synthetic geotextile is different to that of the plain sand - there is a significant reduction in the magnitude of the peak shear resistance and less volumetric change. This factor could be put down to the smoothness of the synthetic polyester fibres and the flatness of the fabric.

Table 3: Shearing interactive values of vegetable fibre geotextiles compared to two synthetic geotextiles

	Geotextiles	kNm^{-1}	Strain %	Ø'max Sand	∝ Ø'max	Ø'r Sand	∝ Ø'r	Ø'max Gravel	∝ Ø'max
	Fill vs Fill			40.5°	1.00	33.1°	1.00	54.7°	1.00
1	Knitted Flax Sisal Inlay	**207**	**8**	40.9°	1.01	33.0°	1.00	50.5°	0.86
2	Knitted Grid Flax Sisal	**144**	7	38.8°	0.94	32.5°	0.98	50.9°	0.87
3	Woven Sisal Warp Flax Weft	**180**	**10**	40.0°	0.98	32.4°	0.97	49.8°	0.84
4	Woven Sisal Warp Coir Weft	**113**	**16**	42.1°	1.06	33.1°	1.00	53.4°	0.95
5	6x1 Woven Weft Rib Sisal Coir	**171**	**8**	42.0°	1.05	33.2°	1.00	50.9°	0.87
6	Woven Coir Geotextile	**20**	**28**	41.9°	1.05	33.1°	1.00	51.2°	0.88
7	Knotted Coir Geotextile	**18**	**53**	43.5°	1.11	36.7°	1.21	51.8°	0.90
8	Nonwoven Hemp	**2**	**56**	39.3°	0.96	34.8°	1.07	44.6°	0.70
9	Nonwoven Coir Latex	4	**6**	34.7°	0.81	-----	-----	36.4°	0.52
10	Woven Polyester	**41**	**8**	40.4°	1.00	31.9°	0.95	46.6°	0.75
11	Warp Knitted Grid Polyester	**46**	**28**	38.4°	0.93	31.8°	0.95	51.3°	0.88

Coefficient of interaction

Values of peak (ϕ'max) and residual (ϕ'r) shearing angles together with their coefficient of interaction (∝) are shown in Table 3, some of these values are above one for the sand (e.g. No. 7 Knotted Coir Geotextile), indicating that by introducing the geotextile in the sand it actually strengthens the ambient sand. This could possibly be due to the surface texture of some of these geotextiles, in that the sand grains can interlock with the fabric and reduce movement. This scenario can be described as if sand were sheared against sandpaper producing a higher frictional resistance than shearing sand against sand. As a result of sand shearing against sand, the sand above and below the failure plane are free to move, but with the sandpaper the sand grains are unable to move. In a practical situation if the ∝ is above one, the failure surface would just be pushed up away from the geotextile into the region of sand against sand.

The fabric structure can be further assessed by applying a flow rule analysis to the soil/fabric interface data, as demonstrated by Pritchard,[1] to enable an assessment on whether a higher shearing resistance was developed from the surface roughness characteristics of the geotextile (smoothness of the fabric) or as a result of interlock i.e. from a higher dilational component (the effect from the apertures and abutments in the fabric).

REVIEW OF THE PERFORMANCE OF GEOTEXTILES TESTED

The main properties required for reinforcing geotextiles for short-term applications can be generalised in that they must possess high tensile strength with low elongation and provide a good shear resistance in the fill used for the construction works. The results summarised in Table 3 show that for the overall performance the geotextiles which were the least suitable for reinforcing applications were the nonwoven natural fibre geotextiles (Nos. 8 and 9). With the knitted and woven vegetable fibre geotextiles performing the best (Nos. 1, 2, 3, 4 and 5) - all of these structures having been created in the Textile Centre at Bolton Institute. Further tests are underway at Bolton Institute on the most suitable vegetable fibre geotextiles to determine inter alia creep and degradation rates.

CONCLUSIONS

Vegetable fibre geotextiles have been found to have superior properties in comparison to the mid-range of synthetic geotextiles, for soil reinforcement, when considering strength and frictional resistance. The high degree of frictional resistance of the vegetable fibre geotextiles was probably developed from both the coarseness of the natural fibre yarns and the novel structure forms.

Although natural fibres have always been available, no one visualised their potential as a form of geotextile until synthetic fibres enabled diverse use and applications for geotextiles to emerge. Manufacturers are now attempting to produce synthetic fibres which will mimic the properties of natural fibres, but at a greater expense. Vegetable fibre geotextiles will be much more environmentally friendly than their synthetic equivalents and the fibres themselves are a renewable resource and biodegradable.

A wide range of new and novel knitted structures have been designed and developed during this research programme, using modified and redesigned flat knitting equipment. Some of these have been discussed in this paper and it is intended to report further developments in these structures in subsequent publications.

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THE POTENTIAL FOR HEMP
LOCALLY PRODUCED ORGANIC TEXTILES

Sue Riddlestone

INTRODUCTION

Hemp (Cannabis sativa) could be an important crop enabling the production of environmentally-friendly, locally produced, high quality textiles in the UK and around the world. Hemp is a traditional fibre crop, which for centuries was important in meeting our needs for textiles, paper and oils. It is easy to produce organically, growing so fast that it smothers weeds whilst robustly shrugging off pests. As a locally grown, low input textile fibre crop hemp could make an important contribution to a sustainable future. Currently cotton and synthetics, both of which have serious environmental problems associated with them, meet the bulk of our demand for textiles.

The once major hemp textile industry has now completely disappeared from the western world. At Bioregional Development Group we have been investigating the potential for reviving hemp and flax cultivation and integrated processing to produce textiles, paper, particleboard and oils on a sustainable basis in the UK.

As part of this work, as a practical experiment, we grew a small trial crop of hemp specifically for textile production. We extracted the fibre from the crop in a variety of ways, by hand, using conventional flax machinery and a novel decorticator. The fibre was machine spun into yarn, which was woven into the first UK grown pure hemp fabric for generations. Our experiments have demonstrated the very real potential for this crop in the UK and around the world as a truly sustainable textile fabric.

Sustainability and bioregional development

Established in 1994, BioRegional Development Group is founded on the green ideal of local production for local needs. The Group takes a market-led approach to sustainable development and promotes the application of appropriate technology.

Local production can bring many benefits:

- reducing freight transport - reducing pollution and environmental damage
- creating employment and wealth in the region
- making good use of local resources and reducing waste
- bringing accountability - reducing imports produced in socially or environmentally damaging ways

Our vision of the future is of a network of regional industries based on sustainable resource use, providing fulfilling employment and maintaining bio-diversity.

Hemp was an important traditional crop in many countries. We believe that a revival of hemp cultivation around the world will make an important contribution to sustainable development provided it is done on the basis of local production for local needs.

Hemp textiles in context

The significance of hemp to the economic and day-to-day lives of our ancestors is increasingly being recognised. It was important for textile, paper, rope and oil production. Indeed, hemp was so important in England in the sixteenth century that King Henry VIII passed an Act of Parliament, which fined farmers who failed to grow the crop. Although hemp was mainly used to produce ropes, sailcloth and sacking, the fabric which can be produced from hemp is comfortable to wear, and this feature, combined with its durability, meant that hemp was a fabric of choice for many working clothes, often in blends with wool. It is interesting that Levi Strauss made his first jeans from hempen cloth imported from Nimes in France, hence the name "denim" which comes from "Serge de Nimes". Also, within living memory Italian women were wearing linen-like dresses made from hempen cloth, which was sold in all drapers' shops in Italy [1].

Today, textile production from hemp has been supplanted by imports of cotton and synthetics. Most cotton production today is highly intensive, heavily dependent on inputs of pesticides, fertilisers and water. The environmental and social costs of modern intensive cotton production are very high. However, in parts of China and Eastern Europe, a small hemp textile industry remains to this day. Samples of Chinese and Hungarian hemp fabric show the quality, which can be achieved.

Hemp, as a fibre crop is like flax (which is used to make linen). Both hemp and flax fibres are known as "bast fibres', that is the fibres are contained in the stem. The processes and machinery required to produce fabric are similar in principle for both crops. Whereas the hemp textile industry has died out in the western world, the flax industry continues with machinery and expertise readily available.

Hemp growing never ceased in France, and in response to concerns about the narcotic uses of the hemp plant low narcotic strains were developed. In recent years hemp has been grown in France to produce paper from the fibre and animal litter and bedding material from the woody core, also known as 'hurds'. Since 1993, hemp has once again been grown in the UK under licence from the UK government. Hemcore, an Essex based agricultural merchant successfully argued that under European Community law, if the French could grow low narcotic hemp then why not UK farmers? In 1995, 1,000 hectares of hemp were grown; 2,000 hectares are being planted this spring. Hemcore are growing hemp primarily to produce a non-allergenic and absorbent horsebedding from the hurds. Some fibre is being pulped to make tea bags, cigarette papers and banknotes, but the production of hemp textiles has proved more problematic.

Growing consumer demand and interest in hemp fabric has stimulated research in this area. We, at Bioregional Development Group, have been working with Hemcore and other organisations to produce experimental quantities of 100% hemp fabric.

We believe hemp merits consideration as a new linen-like, environmentally friendly, textile fabric. Hemp can be grown easily under organic cultivation as it grows so fast that it smothers weeds. Indeed, studies have shown that organically grown hemp has higher fibre yields [2] and improved fibre fineness [3]. In addition, hemp is a multiple use crop. The high value, long "bast" fibres are used to produce textiles, twine, geotextiles and paper. The shorter "tow" fibres from textile processing are also suitable for geotextiles and papermaking. The woody core or hurds are also fibrous and can be used for animal bedding, papermaking or in building materials, such as particleboard. The seed is used for fish, bird or human consumption or for oil production. Growing regimes vary according to whether seed or fine fibre is required. Obviously, aside from the whole crop utilisation, multiple co-products will allow far greater income generation from the crop.

THE "HEMP FOR TEXTILES" PROJECT

In order to explore the value of UK gown hemp as a textile fibre Bioregional Development Group instigated a project "Hemp for Textiles" with funding from the UK Department of the Environment Local Projects Fund and the Konrad Zweig Trust. Hemp for Textiles aimed to:

- grow four hemp varieties (in Kent in Southeast England) to explore any differences in fibre quality and yield;
- extract by different methods a textile grade fibre and produce samples of UK hemp yarn and fabric;
- compare processing techniques and evaluate the best way to establish a UK hemp textile industry;
- make our results available to interested parties and the general public, to advance knowledge of hemp and its potential as a sustainable crop.

The "Hemp for Textiles" project started in April 1994 and is ongoing. It involves private, public and academic sectors.

The traditional method of producing hemp textiles

As a starting point we investigated the centuries old method of hemp textile production[4,5]. In principle it is similar to the method currently used to produce linen from flax. It involved:

1. Sowing the seed densely to produce tall, slender stems, which contain a greater amount of finer fibre.
2. Harvesting after flowering but before the seeds set (the fibre content is reduced and becomes coarser toward seed formation);
3. "Retting" the crop - retting (or rotting) being the name given to the process whereby bacteria and fungi break down the pectins that bind the fibres to the stem allowing fibre to be released; one of two alternative methods were generally used. Water retting, which involves lying the stems in water in tanks, ponds or in streams for around 10 days - it is more effective if the water is warm and bacteria laden; and/or dew retting, which entails laying the crop on the ground for 10-30 days, turning as necessary to allow even retting;
4. Breaking the stems by passing through a "breaker" or fluted rollers.
5. Separating the fibre from the woody core ("scutching") by beating the broken stems with a beech stick or passing through rotary blades, and finally;
6. "Hackling" (combing) to remove any woody particles and to further align the fibres into a continuous "sliver" for spinning. Spinning was either carried out on a wet or dry basis. In the case of bast fibres generally, the best yarns are obtained by wet spinning[6], in which fibres are allowed to pass through a trough of hot water before being spun. This softens the pectin allowing a greater drawing out and separation of the fibres and producing a finer yarn (greater than 12Nm). Dry spinning is cheaper, producing yarns and fabrics with a different appearance and handle.

The hemp for textiles trial cultivation and processing

The first stage of our project was to grow hemp on a trial basis specifically for textile fibre production. This we did in 1994 in Kent in partnership with a Kentish farm, Hemcore (agricultural merchants) and Wye Agricultural College, University of London. The seed was sown at a rate of 55kg/hectare on 11th May (for fibre production 55-60kg/hectare is recommended [7]. Four different low narcotic varieties were grown, two French, F34 and F56 and two Hungarian, Kompolti and Uniko BF. We saw for ourselves hemp's remarkable weed smothering properties and the crop did not suffer from any pests. However, the crop did badly where soil was compacted by tractor wheels, with a reduction in plant height and increased competition from weeds along these "tram lines".

We harvested the crop when the male plants were in flower and shedding pollen and when the stems were whitening at tie base and the leaves were starting to drop as recommended in the literature [4,5]. In our trial the French varieties were ready for harvest on 7 August and the Hungarian varieties on 13 August (Uniko) and 27 August (Kompolti). The crop reached 1-2 metres in height. In our trial we found that the Hungarian varieties yielded 70% greater biomass (as measured after retting) than the French varieties.

We also harvested 600 kg of Hemcore's 2 metre high commercial crop on 24 August using an Allen Scythe, which laid the crop in an even swath. The seed variety was F34, sown on 29 April.

Retting

We chose dew retting as our main test method to produce enough fibre for a spinning trial. After cutting, the hemp stems were laid Parallel in rows to dew ret. The stems needed turning at least once (sometimes) twice in order to allow for even retting. When turning, we observed that the stems closest to the ground remained green whilst the top was retting and turning brown. When retting was complete the crop was entirely brown/grey. The thicker stems took longer to ret. Therefore uniform tall, fine stems would seem to be best for trouble free retting.

Judging the degree and completeness of retting is currently a subjective exercise based upon experience. Retting is complete when the fibre bundles appear white, separate from the woody core and divide easily into individual finer fibres for their full length. Evenness of retting is as important as the degree of retting.

For the earliest harvested crop, retting took only 20 days. For the crop harvested 20 days later retting took 50 days and was incomplete (see Table 1). This was due to a cold, wet spell of weather in September and confirmed our suspicion that dew retting would prove risky in the UK climate.

Table 1: Dew retting.

Hemp Variety	**Harvest Date**	**Retting Time**
F34 and F56	7/8/94	20 days
Uniko BF	13/8/94	22 days
F34	24/8/94	27 days
Kompolti	27/8/94	50 days (incomplete)

Note: Water retting - 20 days at 4-5 °C

Once it is considered that retting has gone far enough, the crop needs to be dried to halt the retting process before it damages the fibre and to prevent further retting in storage. With flax, a moisture content of less than 16% is recommended. We stood the

crop in stooks in the field to dry, but turning and then baling on a dry day would have the same effect.
In our small-scale trials we harvested the crop by hand or with small machines, but if hemp is to be farmed commercially for textiles, special or adapted farm machinery will be needed to;

- cut the crop and lay it in swaths,
- turn the crop to allow even retting, and
- bale the dried stems.

Extracting the fibre from the retted stems

The next step in our project was to investigate the ways in which a fabric could be produced from the hemp we grew. With the resurgence of interest in hemp fabrics, manufacturers of fibre extraction equipment, research institutes, spinners and weavers have all been keen to run trial batches on their machines.

The amount of fibre contained within the stem is around 30% of which perhaps 20% is suitable for textiles. For comparison, yields of flax fibre from traditional scutching methods are 16-18% of long aligned fibre for textiles and 8-10% short fibres (tow) from a similar total of 30% fibre within the retted stem (8). Incidentally, the tow would be an excellent paper making material.

We attempted fibre extraction by two different methods using;

- conventional flax "scutching" machinery (producing aligned fibres) and
- the new "Fibrelin" machine (producing non-aligned fibres) developed in the UK to process flax.

We sent retied stems to Departure, flax processing machinery manufacturer in Belgium, for trial processing on a conventional flax scotch line. The hemp stalks needed to be cut from their full length to 1.5 metres and yields of only 8.5% fibre were achieved (given that unaccepted flax machinery was used, with a scotch turbine adapted for hemp, we should be able to obtain greater yields). To be processed on conventional flax machinery, the stems have to be kept aligned throughout harvesting and fibre extraction. The long aligned "hanks" of fibre thus produced will need to be spun and woven on flax machinery. A flax scotch machine adapted to take hemp could be produced and indeed this is the method used in Eastern Europe to produce hempfibre. However, it is somewhat labour and energy intensive and requires that the stems be aligned at all times.

The remainder of the stems we sent to Silsoe Research Institute in the UK to be processed through their new "Fibrelin" machine. The hemp was successfully processed to produce non-aligned fibres, with a yield of 20-25% fibre. However, the hemp was very "heavy" on the machinery, which has been designed for flax, and a rather more robust version of the machine would need to be built to process hemp.

Processing the fibre produced into a yarn

We sent samples of the fibre extracted by the two different mechanical methods to a number of different spinners for evaluation. A number of processes are involved in preparing fibre for spinning. First the fibres have to be combed, then processed into a sliver which is an assemblage of fibres in a continuous form, then into a rove (a finer sliver) ready for spinning. Preparing and spinning the traditionally produced linen fibre was fairly straightforward for conventional linen spinners. Although as hemp is coarser than flax, the pins on the board for drafting the combed fibre into a sliver needed to be set differently. The rove produced was then boiled in caustic soda to refine it and most of the yarn was bleached with hydrogen peroxide. The rove was successfully spun on a wet spinning system developed by the company Mackie International. Bleached and unbleached yarn of 9.6-10.8Nm was produced.

The non-aligned fibre presented spinners with difficulties, in particular in the preparation of a sliver and rove prior to spinning. The hemp fibres were passed through a breaker card and then a flax card to produce sliver, but losses of fibre were two to three times higher than when processing flax. The hemp sliver "behaved badly" on the roving machine, but eventually a rove was produced. It was boiled in caustic soda and bleached with hydrogen peroxide. Some dry spun yarn was produced, but it was not of very high quality, and was not even considered suitable for carpet backing. The majority of the rove was successfully wet spun to produce a slightly stubby and hairy 6-7Nm yarn.

We observed that the line fibre yarn was smoother, finer and stronger than the non-aligned fibre yarn.

Weaving

Having produced the yarn, weaving is comparatively straightforward, but not without its problems! In order to carry out a machine weaving trial 100kg of yarn was needed. High losses of fibre due to the experimental nature of our work meant that we only had 12kg of yarn in total, but fortunately two textile colleges, Chelsea School of Art and Design and Huddersfield University were keen to hand weave small amounts. We concentrated on producing 100% hemp fabrics for our experiment, but hemp would be suitable to use in blends with wool, cotton or flax.

Generally weavers found the hemp was rather like linen to work with but stiffer and coarser. The line fibre hemp produced was easier to work with and produced better results than the non-aligned fibre yarn. We discovered that in Eastern Europe and historically in the UK hemp fibres were subjected to a softening process prior to spinning. This involves passing the scutched fibres through crushing rollers. If we were to repeat our experiment we would include this step.

Shrinkage was around 7%. We found that the hemp fabrics softened and improved with washing, rather like linen does. Simple industrial or handwashing improved the fabric, softening it, filling out gaps and adding smoothness and lustre.

A British grown and designed hemp garment

Top British designer Katherine Hamnett, well known for her strong commitment to environmental issues, was very impressed with the fabric produced from the line fibre and offered to design and make a garment from it. A lightweight summer blazer was produced, a picture of which can be found on the BioRegional Groups web page (bioregional.com).

What niche will hemp find in the textile market?

The fabrics and garment produced from our Hemp for Textiles trial are impressive, the bleached line fibre hemp fabric in particular. The line fibre hemp could be produced in the same manner as flax linen and for a similar cost. Hemp fabrics are in fact very similar in appearance, handle and other properties to flax and industry wisdom would say that there would be little to be gained in producing hemp unless it had some advantage - unique selling point - over flax. In certain respects hemp has some disadvantages when compared to flax. Its spinning limit (fineness) seems to be lower; about 12-14 Nm compared to 35 Nm or more for flax - though extremely fine hemp yarn at 30 Nm is apparently produced in China. A textile consultant has estimated that bearing in mind hemp's similarity to flax and it's likely lower spinning limit it would seem that hemp would only be successful as a textile fibre for the international markets if its price came somewhere below flax and above cotton. At the same price as flax there would of course, still be a market, but it would be small. However, the potential to grow hemp organically, which is difficult in the case of flax, would assist hemp gain a place in the small, but growing, market for eco-friendly products.

Tests were carried out at Huddersfield University this year to ascertain hemp's suitability as a furnishing fabric. Chinese hemp fabric, usually used for waistcoats, was compared with 100% cotton and a flax/synthetic blend. The hemp fabric had superior tear and break. The hemp was slightly less resistant to abrasion than the other fabrics, being most suitable for heavy domestic use.

Bearing in mind hemp's particular properties, the types of fabric and uses that hemp would seem to be most suited to are:

- the furnishing fabric area, especially drapes, and;
- "bottom weights" in clothing; perhaps jeans and sportswear, in both 100% hemp fabric and blends with cotton, linen or wool and with synthetics.

At the moment it is difficult to estimate the size of the potential market except to say that it is somewhere, depending on price, between cottons 50% of total fibre consumption and flax's 3%.

Technical problems to be overcome

We are pleased with the results of our experiment, as we succeeded in producing the first machine processed, UK grown 100% hemp apparel fabric probably this century. In the short term we feel that it would be possible to establish hemp textile production in Southern England to produce high quality hemp yarn and fabrics at a similar cost to linen. However, if hemp is to be grown and processed in cooler climates or at a more competitive price there are two technical problems, which would need to be overcome.

Firstly, as hemp is harvested late in the season (a month later than flax) dew retting of hemp is unreliable. Therefore we must develop retting technologies that are suitable for our temperate climate, or bypass the need to depend on the weather. A lot of work has been done on retting flax, particularly by the French. In the UK we are also trying various techniques but it is too early to asses their probability of success. A great deal of work still needs to be done. What is certain is that unless the problem of retting is overcome we will not be able to produce textiles from hemp in countries where the climate is unsuitable for reliable dew retting.

The second problem is technically easier to overcome, but still needs substantial research and development. After retting the hemp stems, the fibre needs to be removed from the rest of the plant. As we have discussed, adapted flax machinery can be used, but it is not entirely suited to hemp which requires a more robust machine, and unless cutting the stems in half as we did for our trial, a much larger machine. We believe that the problem could be rapidly solved if the market demands the final product.

Concerning the further processing of hemp to produce the finished textile: We know that wet and dry flax spinners can adapt their machinery to handle hemp without too much difficulty, particularly the line fibre hemp. There is some practical experience in spinning hemp fibre in blends with cotton but as far as we know, no experience of blends with polyester or acrylics. As environmentalists we would prefer not to blend oil based synthetics with hemp but have been told that the addition of 10% of synthetic material greatly improves abrasion resistance and extends the range of end uses for hemp. For blends, it would probably be necessary to cut the hemp fibre to required lengths, but this will not prove to be a problem if the market is as substantial as expected. We foresee no particular problems in commercial weaving, dyeing and finishing.

Potential Yields

From the information that we have gathered we can calculate the amount of fabric that could be produced from each tonne of hemp if it were produced on a commercial scale (see Table 2).

One tonne of hemp could comfortably be grown on 0.2 hectare (approximately 0.5 acre). A tonne of hemp would produce at conservative yields of 15%, 150 kg of line or high quality fibre. We should expect losses of 35% in hackling or carding, 5% in yarn production and a further 20% in boiling and bleaching the yarn to accept dye. This would leave us with 73 kg of fine hemp yarn producing 182 square metres of 400 gsm (jeans weight) fabric.

In addition, 100kg (10%) of shorter tow fibres would be generated which could be used for paper making or geotextiles and 500 kg (50%) of hemp hurds which would make excellent building materials or paper or can be sold as animal bedding. Whole crop utilisation is obviously beneficial from both an economic and an environmental point of view.

Table 2: Predicted conservative yields of fabric

0.2 hectares, (1 tonne) hemp
↓
150kg textile fibre
↓
97.5kg sliver
↓
73kg yarn
↓
182 square metres of 400 gsm fabric

CONCLUSION - OPPORTUNITIES AND CHALLENGES

We learnt an enormous amount from our Hemp for Textiles trial. We have written up the results along with details of hemp for textiles in UK history and around the world in our report "Hemp for Textiles" [9]. The major conclusions of our trial are that:

- hemp can be grown and dew retted in our bioregion south-east England, to produce textiles;
- the Hungarian hemp varieties we trialled have a higher yield than the two French varieties;
- flax processing machinery can be adapted easily to process hemp;

- line fibre hemp (from a 'scutch' mill) produces yarn and fabric which are noticeably superior in quality and strength to the non-aligned fibre hemp yarn and fabric;
- boiling with caustic soda, bleaching with hydrogen peroxide and wet spinning on flax machinery produced the best results.

We are greatly encouraged by the results of our experiment. Hemp, as a crop suited to organic cultivation has considerable potential as a new eco-textile, but the achievement of this potential is not certain and will require both hard work and investment. However, we believe that the revival of hemp industries world-wide would have many environmental, social and economic benefits- but if it is another internationally traded commodity, but if it takes place in the context of local production for local needs and whole crop utilisation.

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WHERE NOW WITH FR?

Peter J. Wragg

"The desire for textiles having a reduced tendency to ignite and burn has been recognised for considerable time during man's recorded history." [1]

Textiles are used widely in our environment; textiles in general have a tendency to burn and their use will bring an increased hazard to the occupants of buildings or vehicles where the textiles are used. In certain working environments, the clothes we wear may add to our risk. Flame retardancy has a role to play.

No one should see their business as being immune from the pressures of controlling their environmental impact but it is difficult to conceive of a time when flame retardant treatments for textiles will not be needed.

There are, of course, many ways to approach the question of the environmental impact of flame retardant treatments for textiles including fibre and fabric selection. The arguments over natural versus synthetic fibres for instance are not the subject of this paper. Nor is the question of adding flame retardant when polymers are made or to treat in fabric form as topical treatments.

Schill and Seilacher are involved in topical treatments for textiles as a way to solve flame retardancy questions and their answers are applicable to both natural and synthetic fibres.

HEALTH AND SAFETY.

What constitutes a threat to the environment is often also seen as a threat to Man. The control over chemicals in the work place continues to extend with our knowledge of the effects of using chemicals. This information is disseminated by sophisticated information systems throughout the World. It is also a requirement, certainly in Europe, that this knowledge must be passed to the users of the chemicals.

The system of placing information into the hands of users through Product Safety Data Sheets has been strengthened and they must by law have a document that sets out in detail risk and safety information that relates as much to the environment as operative safety.

The health and safety controls are intrinsic to flame retardant treatments. Labelling systems such as the Oeko-tex scheme have shown relatively little effect on what we do as flame retardant treatments are generally excluded. The main problem with such labelling schemes is the potential for conflict with meeting Statutory Performance Requirements. The effects can be mutually exclusive.

CHEMICAL ASPECTS

Flame retardant treatments, at the end, must be viewed in terms of chemistry used and polymers treated i.e. in the context of natural or synthetic fibres as polymers. The fibre type or types involved determine which type of chemistry can be used to render the textile flame retardant.

The chemistry employed in the flame retardant treatment of textiles [1] and application criteria [2] are described elsewhere.

Basically compounds based on phosphorus, halogens, antimony (as the trioxide) and some nitrogen and sulphur are used. These will be used as both inorganic and organic forms and as solutions or as emulsions of water-immiscible materials and dispersions of insoluble materials.

High levels of product deposit are required to achieve FR effects. Flame retardancy requirements follow on from the establishment of test methods and performance criteria. To this end there is a strong incentive to control what is applied and how it is applied if meaningful results are to be achieved.

Durability - almost without exception - comes from two sources; the chemicals used are insoluble or can be rendered insoluble by the process. Self-reacting chemistry or fibre-reactive chemistry can achieve the latter factor. This has implications for the choice of chemistry and process used and subsequently for the environmental Impact of a treatment. The significance of durable as opposed to non-durable treatments is critical in the chemistry of flame retardant treatments.

Oxygen is necessary for combustion but this point has no significance for the textile treatments. It should be stressed that there is a difference between the burning process in a fire hazard and waste disposal by burning. The control of the latter, both in terms of Regulatory Consent and the technical control of the process, are relevant and important factors.

APPLICATION METHODS.

Application method is of equal importance to fibre type and chemistry in the flame retardant treatment of textiles and so the amount of chemical applied must be controlled if the desired effects are to be achieved and quantitative methods are normal. Thus padding or coating methods are used to apply chemicals and very seldom are long or exhaust baths used. These methods offer a good way to minimise and/or control waste.

Various methods are used to achieve economy in application and these must also be linked to an environmentally aware approach. The main waste from a process is the amount left in the bath or on the coating blade and how much water is required for cleaning is an issue. Savings are possible by using baths of higher concentration diluted with air, e.g. foam application. Here waste and need for solvent evaporation is reduced. Foam systems and similar can be used in conjunction with a pad mangle or coating applicators. Systems such as enclosed slot applicators using screen print concepts, can lead to significant reduction in end liquor volumes, evaporation demand and wash-down volumes.

The demand for economy can deliver environmentally improved processing.

The next generation of change will be airborne emission controls for drying and curing processes. Reactive systems will be more difficult to control than those starting with insoluble materials. The questions will be asked, "What can we do and how much does it cost to solve the problem?" It is not clear in every case that the answer will be in improved emission controls from machinery or an avoidance of using certain chemical systems. The answer to the questions will be dependent on each company's circumstances and the value of the business.

CHEMICAL CHOICE

There are two fundamental points in choosing which chemicals we shall use to achieve a certain requirement:

what is available? and

what can the customer use?

There are various aspects to this type of control and the consideration of various useful chemicals may best demonstrate the point.

Phosphorus

Phosphorus is particularly good for cellulosic fibres and it is used in several chemical forms. Its effect is improved by the incorporation of nitrogen, as typified by the water-soluble salts based on ammonium phosphates. It can also be used as organo-phosphate esters that show improvements in hygroscopic nature and fabric handle. Durable effects are produced based on variations on the tetrakis(hydroxymethyl) phosphonium group (THP) or the N-dimethylol-phosphonopropionamide molecule. Here there is a requirement for curing conditions and a reaction that is not quantitative or even stoichiometric. Self-reactive systems use a specialised ammonia cure system and fibre reactive systems use a formaldehyde-based resin system. Normally unfixed chemical must be washed off and waste volumes are increased. There is likely to be more control on emissions from processing by air and water under future controls. Otherwise these P-containing species face little restraint on their use excepting that they are limited to cellulosic fibres in the main. The main problem seems to be in achieving the desired quantitative effects and deciding how durable they are. They have a role in certain product areas where launderability is essential. The temperature of reaction for hot-cure systems is also near to the point of degradation and discoloration of cotton and so strength-loss can be a problem.

The main problem is that we cannot turn simply to phosphorus when we need treatments for synthetic fibres and also need durability. There is a steep increase in cost as the chemistry becomes more complex and results are not completely effective. Phosphorus cannot for instance be so easily produced as an insoluble pigment form in the same way as bromine/antimony systems. There is a limited amount of use of phosphonates that can give results of excellent durability on polyester but the volumes are not significant.

Antimony Trioxide

This has little if any effective flame retardant but

- shows excellent effects in synergistic mixture with halogens,
- shows effects on most fibre types and is especially good on mixed fibre fabrics,
- is relatively cheap except when the source mines are flooded,
- is relatively inert and has very low solubility, and
- has a very high specific gravity.

For disadvantages, however, the following holds true:

- it is an insoluble white pigment so is generally limited to backcoating and technical fabric applications,
- it has recorded risk as a dust,
- it is almost without exception applied to textiles in combination with a binder that will encapsulate the particles,
- it is soluble in strong acid - this is relevant for EN 71/3 articles i.e.children's toys and the same criteria would be applied e.g. to children's furniture, and
- the recent Cook Report on BBC television implicated it in Sudden Infant Death Syndrome.

Schill and Seilacher have invested a great deal of money in equipment for handling antimony trioxide as a raw material. After a wet dispersion has been created there is no difficulty in handling. Supervised control of this process is without a problem as are production, storage and shipping. Most customers can use antimony trioxide without problem and many tonnes are used each week in the UK. There are controls applied on discharges in waste in most countries but it can be easily isolated in wastes due to its lack of solubility and high specific gravity. In Holland, though, effluent discharge restraints are set at levels of grams per year and this produces an effective ban on its use. They also limit phosphate and organic bromine discharges so there is very little flame retardant processing in Holland.

The BBC Cook Report in 1995, though is an interesting case in point. Following the programme there was a considerable amount of intensive inquiry to locate where antimony could be found in use and what could be done to avoid it. This was nothing better than a panic reaction at best as little hard evidence was presented. Nevertheless, very real concerns were expressed i.e. real in the sense that there was pressure against the use of antimony trioxide.

My letter to the Lancet of March 1995 [3] gave a clear rebuttal of the stand taken by the programme. One of the effects of any avoidance of antimony trioxide (following the Cook Report) would likely be an increase in the amount of organic bromine used to compensate, which would seem to be a negative effect in terms of environmental acceptability.

Halogens

In flame retardant treatment terms chlorine is quite an effective flame retardant and bromine is highly effective. Both may be met as inorganic forms but the interesting forms are organic. There are many papers dedicated to the application of halogens in general and bromine in particular [4]. Bromine is also an important flame retardant for the plastics industry and more is used than in textiles. The most critical point in halogen chemistry is that they are involved in the formation of dioxins at higher temperatures where pyrolysis in insufficient oxygen prevents complete combustion. There are about 14 dioxins or furans of varying toxicity that cause concern. They are too toxic for use but can be formed in small measure during synthesis and as side reactions when aromatic halogens are burnt. This also applies to the pyrolisis of aromatic bromine sources and can occur in the burning for disposal of waste. This is a temperature-related effect. Control over the burning process is important.

There are many species of organic bromine. It is important to appreciate the differences and similarities between the different available organic bromine sources.
The following are relevant questions to ask:

(i) Do they contain free dioxin from the manufacturing process?
(ii) What is the physical from – liquid or solid?
(iii) Can they be broken down in the environment and if so what are the decomposition products?
(iv) How easily will they yield dioxins on disposal- in particular by burning?

There are orders of difference in dioxin yield potential as micro contaminants, instability or from pyrolisis between different chemical species. Many of the worst offenders are already banned from use in Europe. The main bromine sources for Textiles are the aromatic form decabromodiphenyl ether or DEKA and the aliphatic form hexabromocyclododecane or HEXA. They are both insoluble white pigments of high specific gravity and can be dealt with in terms of concentration and isolation for disposal. There are little or no concerns over handling although they are usually effectively combined with antimony trioxide to increase effect or reduce usage levels. In this case the controls for antimony trioxide would be applied also. It should be noted that the use of organic bromine sources such as DEKA and HEXA in general textile processing does not cause an increased risk.

Variants such as Oct- and pentabromodiphenyl ether may contain traces of dioxins from manufacture and produce more on burning [4]. Their use in textiles is limited but they could be used as plasticisers in coating formulations to improve fabric handle in spite of a potential effect on soiling. Schill and Seilacher do not use either of these products but there is no consistent evidence that restraints are generally applied.

There have been moves to ban, avoid or limit the use of aromatic bromine chemistry in some European countries and, whilst there are not necessarily bans in place, there are measures in place that require their avoidance. This is a fine distinction perhaps but a well operated system in my understanding as far as Germany is concerned.

The best demonstration of this is to contrast events in Germany and the UK. In the UK there has been a very formal official response to dioxin hazards and much has been said about "safe levels". In Germany it is common to see roadside banners campaigning against waste incinerators that are phrased in terms of "no dioxin here" i.e. a public statement of "zero tolerance" and a specific reference to the chemical species.

Schill and Seilacher have conducted research work that shows that the Aliphatic forms of organic bromine yield notably lower levels of dioxins on pyrolisis than Aromatic forms. Some Countries require the choice of certain types and the avoidance of others. The chemical industry group to which Schill and Seilacher belongs asked for a general ban on the choosing of aromatic bromine sources in Germany. There is no comparable situation in the UK - where we do sell them where they are accepted in use outside Germany. That is a commercial question – there is no other pressure applied and the response is purely commercial and acceptable in the UK market.

But the general picture is further distorted. For instance reference 4 contains a statement to the effect that "...if PBDPEs were banned then it could be difficult, if not impossible, to pass the UK (Upholstered Furniture (Fire) (Safety)) Standard". Schill and Seilacher have avoided the use of aromatic bromine in their upholstered furniture backcoating formulations sold in the UK and have no problems in achieving effects. Schill and Seilacher advocate the choice of HEXA as an organic bromine source in this case.

This can be compared with the automotive industry (see Figure 1). Here flame retardant requirements will vary but it may be a requirement to avoid certain chemical species. Suppliers and users will be found in many countries and then the potential for a very complex picture of what can be offered for application is present. But these lists seem varied in their selection criteria. Certainly some comparison can be seen with the so-called UK Red List of Chemicals. In the UK the Environmental Agency will certainly take interest when chemicals that appear on the Red List are used and hence could be found in effluent discharges. This bears close comparison with the situation of the biocide lauryl pentachlorophenol (LPCP) with regard to its chemistry, control and use in Europe.

Halo-Phosphorus Systems.

There are a group of chemicals of highly effective flame retardant performance where phosphorus and halogens are linked in a single molecule. Tris (dibromopropyl phosphate) - commonly referred to as TRIS – is typical and it was banned from use as a proven carcinogen during the 1970's.

There is a basis to be suspicious when there is a close proximity of phosphorus and halogen in the same molecule. Schill and Seilacher have chosen to be cautious in this respect and we avoid a wide range of potentially useful chemicals. There are some companies that avoid their use and others that do use them. Trichloroethylphosphate, for example, is widely used in the UK but in our experience, as a plasticiser it is too "mobile". The need for a so-called clear finish for upholstery

Figure 1: Typical listings of controlled chemicals

AUTOMOTIVE PRODUCER

FORBIDDEN

CFC AND HCFC
TRIORGANIC TIN AND ITS COMPOUNDS
METHYLENE CHLORIDE
TRICHLOROETHYLENE
TETRACHLOROETHYLENE
BROMINATED FLAME RETARDANTS
CHLORINATD PARAFFINS
ASBESTOS
CADMIUM AND ITS COMPOUNDS
MERCURY AND ITS COMPOUNDS
1,1,1-TRICHLOROETHANE
CARBON TETRACHLORIDE
4-NONYLPHENOL
POLYCHLORINATED BIPHENYLS
POLYCHLORINATED TERPHENYLS
DI-N-BUTYLPHTALATE (DEP)
BUTYLBENZENEPHTALATE (BEP)
NONYL PHENOL ETHOXYLATES

TO BE AVOIDED

ARSENIC AND ITS COMPOUNDS
LEAD AND ITS COMPOUNDS
DDT
1,4-DICHLOROBENZENE
DIELDRIN AND OTHER'DRINS
HALOGENATED FLAME RETARDANTS
HEXACHLOROBENZENE
ATRAZINE
BENZO(A)PYRENE
BENZIDINE
HEXACHLOROBUTADIENE
HEXACHLOROCYCLOPENTADIENE
4-CHLOROANILINE
COPPER AND ITS COMPOUNDS
CHROMIUM AND ITS COMPOUNDS
LINDAN
OCTACHLOROSTYRANE
ORGANIC TIN COMPOUNDS
PENTACHLORPHENOL
PHTALATES
SILVER AND ITS COMPOUNDS
2,3,7,8 TETRACHLORDIBENZODIOXINE AND OTHER PCDD incl. PCDF
TIURAM
TOXAPHEN
TRIPHENYLPHOSPHATE
1,2,4-TRICHLOROBENZENE
2,4,5-TRICHLOROPHENOX ACETIC ACID
XANTATER
FLUORINE

THE UK RED LIST

PENTACHLORPHENOL
HEXACHLOROBENZENE
HEXACHLOROBUTADIENE
ALDRIN, DIELDRIN, ENDRIN
POLYCHLOROBIPHENYLS
TRIBUTYLTIN AND ITS MERCURY
CADMIUM
LINDANE
DDT COMPOUNDS
TRIPHENYLTIN AND ITS COMPOUNDS
DICHLORVOS
TRIFLURALIN
1,2-DICHLOROETHANE
TRICHLOROBENZENE
AZINOS-METHYL
FENITROTHION
MALATHION
ENDOSULFAN
ATRAZINE
SIMAZINE

fabrics that could meet the requirements of the UK Upholstered Furniture (Fire) (Safety) Regulations has long been talked about although little is used. In general, such treatments based on the use of highly flame retardant plasticisers could be best avoided on the grounds of health risk. It must be recognised that there is little control of such usage in the UK system as it works today.

THE CURRENT POSITION

TRIS was banned just as it had started to find wide use in flame retardancy treatments for textiles. In the 1970's finished textiles were actually withdrawn from sale. Still today we seem to have no universal method for determining how we should deal with the issue of control. In the past Schill and Seilacher have sold a dry powder form containing antimony trioxide, but this was withdrawn as new regulatory controls were applied during the early 1980's based on new knowledge and a consequent new hazard assessment. This remains the present basis for hazard labelling of products containing antimony trioxide. While investment in proper handling equipment may be feasible, if limitations are applied on effluent discharges by users, as in Holland, then we have no chance to sell our product. If they should decide they are unable to use the product then we must seek alternatives or the customer must stop producing that fabric.

In general we now have a further question to add to the list of information required before we can successfully offer a complete answer to a flame retardancy question, "What are the environmental implications?"

There is a strong element of looking for antimony/bromine-free systems as replacements in certain countries. Most often this question arises from customers applying new environmental standards - the so-called Automotive List is typical in this case.

There are answers, sometimes at higher cost, but it must not be forgotten that the standards will and must be applied to the flame retardant effects.

There is a wide gulf of difference between what I could term as environmental purists and environmental pragmatists. Too often a commercial question will over-ride in some countries where others will look to advance the level of control, so on a European scale the problem seems to get worse and not better. The real problem comes when organisations have differing views or expectations without an understanding of a common view. These are very real and justifiable concerns over organic bromine, but combining them together with a comment that we do not need them does not help the case against them. But neither is the argument advanced when products that are questionable are used without question. There is not a consistent approach to what is considered to be suitable for control and indeed how it can be controlled. There is a big difference between controlling waste discharge levels and having a total ban on the use of a whole range of "chemistry".

There is a demand for more consistency in our plan of action for the environment that must extend from the technocrats and politicians to the consumers and voters. Perhaps a more rapid application of an ISO standard as with quality is the most realistic way forward.

THE FUTURE

Two years ago our Applications Laboratory was asked if they had a system to FR a polyethylene non-woven textile. Worse still, it should be a durable system. Such fabrics have zero absorbency and any finish applied will lie on the surface as crystals.

Durability requires fixing a chemical to the textile that is non-absorbent and generally does not offer a key to binders i.e. nothing will stick. Solvent-based systems would be environmentally undesirable and impractical in the work place in question.

Our answer was developed from our growing interest in melt adhesives and a carbon based intumescent system. The basic concept is not new and Schill and Seilacher have filed a patent application for a system that can be applied as a scatter coating of powder adhesive giving excellent adhesion to the surface of the non-woven and good particle binding. The drying phase of wet systems is avoided by using a two-stage adhesive melt we can further laminate a second fabric to the fabric to conceal the flame retardant. As the product comes in "Black Only", this has advantages. It will not prevent thermoplastic fabrics from being thermoplastic, but it is possible to produce non-ignitable treated fabrics.

It has also been applied to floor coverings and the adhesive system holds the carbon particles in place during processing and wear, i.e. they should not migrate out of the fabric. Experimental polyethylene base fabrics treated with intumescent from 100 to 400 gsm to which a 100% nylon face fabric was bonded. Testing was made to DIN 4102 B1, Test 14, Radiant Panel Test. Results show that the heat emission values in watts / cm^2 and the lowest add-on raises the performance above the pass level. The amount of burn damage shows significant improvement with intumescent add-on, as shown in Figure 2.

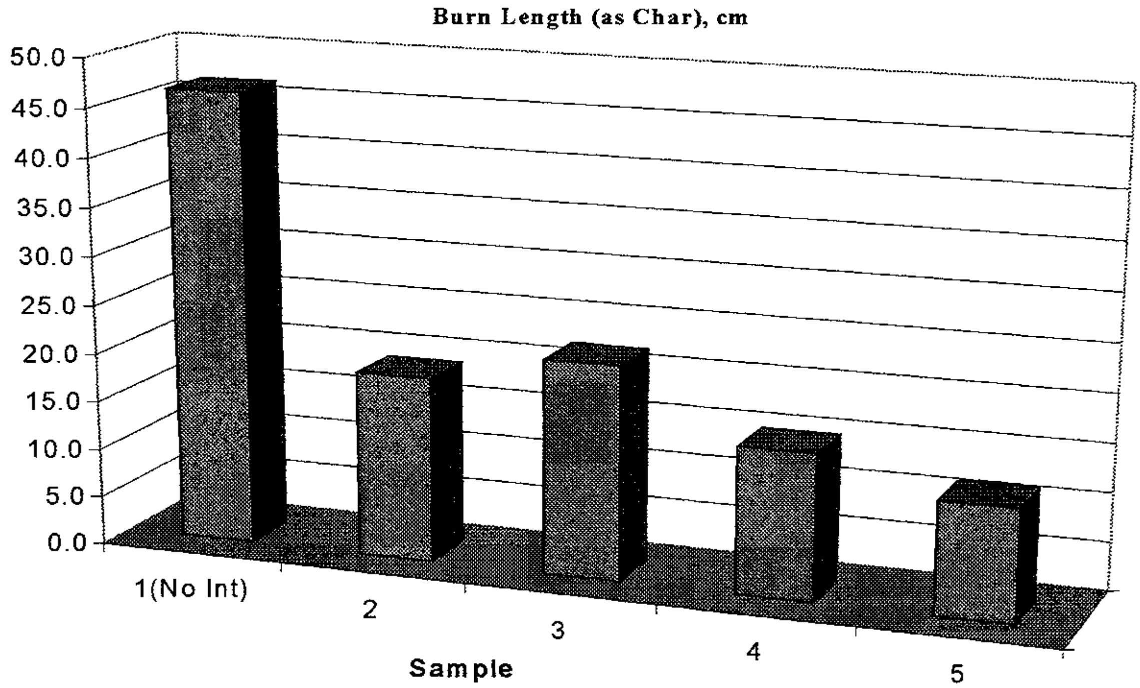

Figure 2: Burn lengths for samples 1 with no intumescent and samples 2 (100 gsm), 3 (200 gsm), 4 (300 gsm) and 5 (400 gsm) with intumecent

Figure 3 below shows that the untreated cloth is already acceptable on the integrated smoke values although with only a small margin for safety, whilst the higher add-on values are of a different order of performance. Obviously the system has excellent effects, but is far from an ideal answer to all flame retardancy questions. On the other hand results demonstrate that for a hydrocarbon fabric, apart from modifying the hydrogen, carbon and oxygen balance, no phosphorus, no halogen, no antimony is present and yet acceptable FR properties have been achieved.

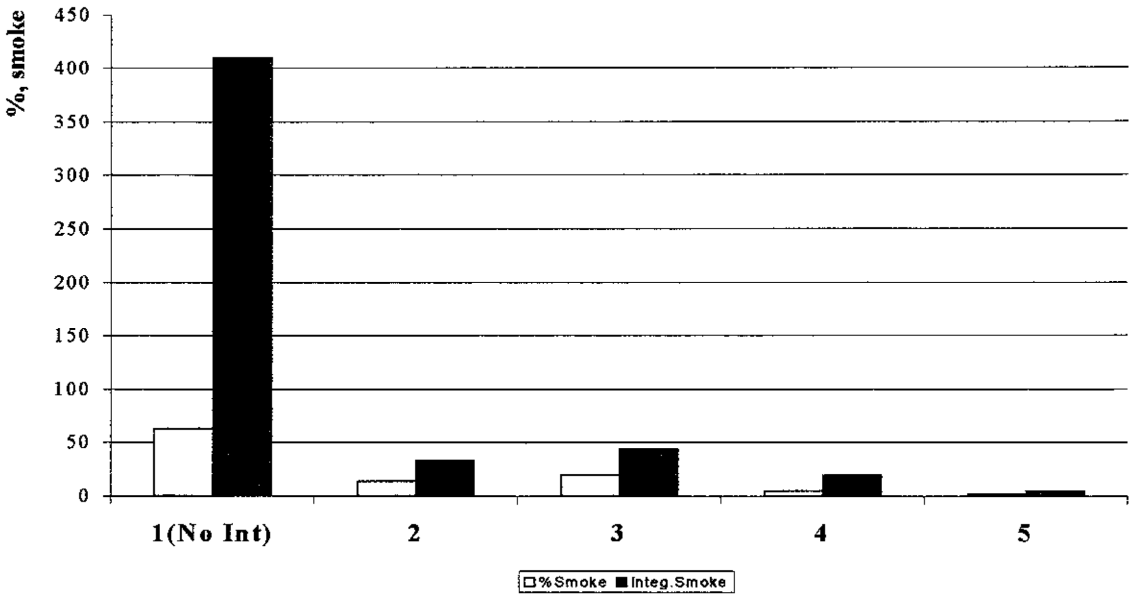

Figure 3: Smoke emission as percentage and integrated percentages for samples as in Figure 2.

Clearly, the use of carbon graphite intumescent systems of this type does offer a more environmentally acceptable alternative in spite of its limitations in terms of colour, although this is not a problem in the above example.

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