Section 5: Environmental Impact Analysis

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LIFE CYCLE ASSESSMENTS : - AN AID TO ENVIRONMENTAL MANAGEMENT AS APPLIED TO PET (POLYETHYLENE TEREPHTHALATE) CONTAINERS.

Vince Matthews

INTRODUCTION

The EU's current environmental policy stems from its Fifth Action Programme (1993 to 2000) recognising the need to integrate environmental considerations into all other policy areas and thus bring the goal of sustainable development closer to every day activity. 'Eco-auditing' of all activities is now a fundamental part of business activity and environmental impact reports usually precede the launch of new developments.

Sustainable development?

This is a phrase that we do hear quite a lot and there are many different ways of describing this process. Generally sustainable means 'capable of being continuously maintained over time'. Environmentalists have a particular concern to leave something for the generations to come and want to develop systems which can be repeatedly regenerated - in perpetuity if you like.

It is an easy concept to understand but very difficult to apply in the way the current world operates. I am sure many of you in the textiles world are familiar with groups who advise using natural fibres to avoid wasting plastics/polymers which are derived from fossil resources. Is this a sustainable recommendation? Synthetics offer wear properties, which are several times, the cotton and wool equivalents. They are much tougher, lighter and more effective in many end-uses. Combinations with natural fibres are unique in wash wear properties and save in many ways. Harvesting wool and cotton demands a great deal of resource in terms of climate and land. Is it practical to replace synthetics with them?

Growing cotton can only be done in specific areas of the world with the correct temperature and water balance. Growing wool to replace directly 20m tonnes of synthetics will require a land area of over twice the EU. Obviously a balance is required and we really need to look carefully at optimising our resources in environmental terms. Defining goals is easier than designing realistic systems to achieve them.

Another feature of sustainable development is waste avoidance, re-use and recycle wherever possible. In the early years of environmental activity this aspect was pursued with great vigour, some would say to the extent of losing sight of the goal which is to use less resource and produce environmental gain. This determination on the part of the EU certainly focused industry into looking very carefully at its operational systems and looking to maximise environmental benefit. However, actually measuring the benefit was not always easy, certainly for complex systems. This led to the more rapid development of Life Cycle Assessment techniques.

This paper explains the technique briefly and looks at how PETCORE has started to apply LCA thinking to look at PET recovery systems

Table 1. Natural fibre yields

Cotton yields 1 kg from 18m2 land area
Wool yields 1 kg from 404 m2 land area
source - Liverpool Cotton Association & British Wool Marketing Board

World Synthetic Fibre Production est. 1996. [Chem. Fibers Int. 47 (1997) 4; 248-250]

Polyester	12.9	
Polyamide	3.9	
Acrylics	2.6	
Total	19.4	m tonnes

20 m tonnes cotton requires approx. 350,000 km2 land area
20 m tonnes of wool requires approx. 8m km2 land area

Germany has a land area of approx. 350,000 km 2
The USA has a land area of approx. 9.2m km2
The European union has a land area of approx. 3.5m km2

WHAT ARE LIFE CYCLE ASSESSMENTS?

LCAs are now accepted as the best available technique for measuring or quantifying the effects of linked process systems in environmental terms. LCAs describe the performance of a system in terms of

- consumption of energy
- consumption of raw materials
- emissions of solids, liquids and gaseous wastes

and an evaluation of potential environmental impact.

A complete LCA will start with raw materials out of the earth, follow all processing sequences, i.e. industrial and consumer operations until final disposal of the product at the end of their useful lives. Put simply - elements out of the earth to elements back into the earth. Eco-balances, eco-profiles, life cycle analysis, cradle to grave are other terms describing all or parts of this process.

It is important to note that LCAs of products do not exist. It is the process of manufacturing the product or delivering the service, which is the subject of the LCA, i.e. the operating system that does the work.

If the particular system is known and defined, then it is possible to measure what goes in and what comes out, i.e. inputs and outputs. It is important to define the system under study very carefully indeed and set the boundary limits. If this is done it is possible to compare systems even if they produce products, which are notoriously difficult to compare. How often do we hear the statement that someone is trying to compare apples with pears or oranges, meaning that such comparisons are not valid? LCAs can help us to do this. In LCA comparisons the emphasis is firmly placed on the systems and not the products. A generalised scheme is illustrated in (Figure 1).

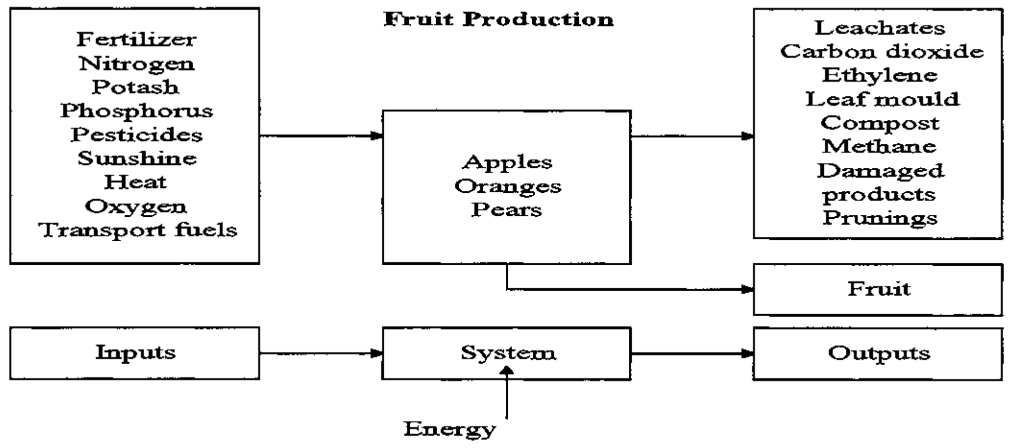
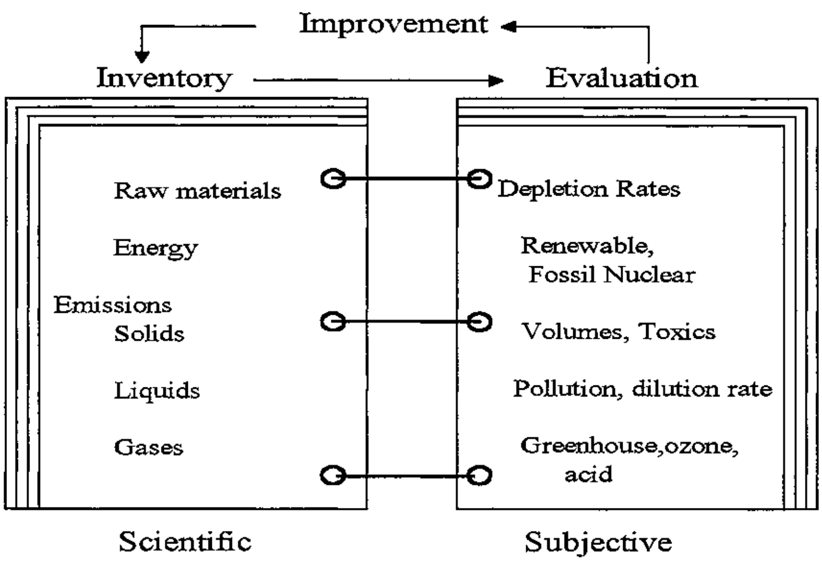


Figure 1

From these examples it can be seen that comparisons of systems can be quantified but comparisons of products is a totally different matter and difficult to maintain real scientific objectivity. A great deal depends upon personal preference or how a value is placed on particular product by the individual, group, government, customer or consumer. Each one of these will have a different need or criteria by which they will evaluate. (see Figure 2)



Simplified LCA principle

Figure 2

The two major parts of an LCA are the ***Inventory*** and an ***Evaluation*** (Figure 2). These two must be kept separate otherwise it becomes virtually impossible to be objective in the true scientific sense. Very often a third phase is included in such studies, known as the ***Improvement*** phase

The *Inventory* is the detailed description of raw materials and fuels used in the process system (inputs) and the solids, liquids and gaseous wastes arising from operations of the system (outputs). The major output is of course the product being manufactured. This part of the LCA can be equated to the currency figures listed in a financial balance sheet. The inventory process is very well developed and falls well into standard scientific methodology, most practitioners of LCA procedures use similar techniques for this stage.

The *Evaluation* phase measures the effects of the inventory outputs in terms of their impact on the environment. For example, contributions to greenhouse gases (carbon dioxide, methane) or ozone depleting gases (chlorofluorocarbons - CFC's). This stage of the process is NOT very well developed, assessment criteria are subject to 'pressure group' influence and acceptable techniques for weighting or ranking of criteria needs a great deal of further study.

The *Improvement* phase covers modifications to the process system to reduce the particular environmental impact desired, for example explore the use of alternative energy sources to reduce carbon dioxide emissions or seek alternatives to CFC's to reduce the effects of ozone destroying gases or introduce recycling.

Setting a clear objective before commencing the study is vital in terms of measuring the items that matter. There is little point in measuring all minor gaseous emissions if the major objective is to reduce solid waste. Similarly it is also misguided to concentrate selectively on solid waste if the objective is to reduce overall environmental impact.

All consuming processes use up raw materials and energy and in the process generate wastes in the form of solid, gaseous and liquid emissions (Figure 3). However, for the purposes of this paper only the energy consumption is considered by way of illustration.

ENERGETICS OF RECYCLING SYSTEMS AS APPLIED TO PET CONTAINERS

Introduction

The data in this section has abstracted information from a variety of sources in order to look at the methods of reprocessing collected PET containers from an energy consumption viewpoint. This practice is no substitute for carefully constructed individual assessments of specific schemes. The information should be used a guide only.

It is not always fully understood that the very practice of recycling itself is a consuming process, which demands the use of resources in the form of energy (electricity and fuel oils), and materials, especially water for the cleaning operations. Any such operation should measure the resources consumed very carefully and in theory should not be continued if the overall consumption of resources exceeds the equivalent value in the materials being recovered. Such operations only exacerbate environmental damage.

Participants in recycling schemes are often very quick to claim benefits without conducting the full environmental audit the operation demands. Different sectors of society place a range of value priorities on environmental criteria which are not always the same ranking in each sector. Removal of litter is always a desirable objective and is often linked with recycling - however, it is unlikely that any recycling operations will have a major impact on litter.

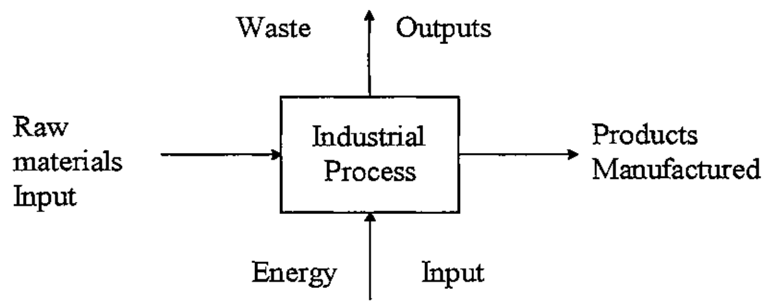


Figure 3: Input output model of a simple industrial process

Society does need to clean up its litter but sometimes the use of resources for recycling can very quickly exceed the value in the materials targeted. A decision has then to be made if specific benefits are considered worthy of the effort - e.g., a litter free environment or more emissions and use of energy from the clean up process. A decision is then made for social reasons and it should be understood that overall environmental benefit might not always accrue.

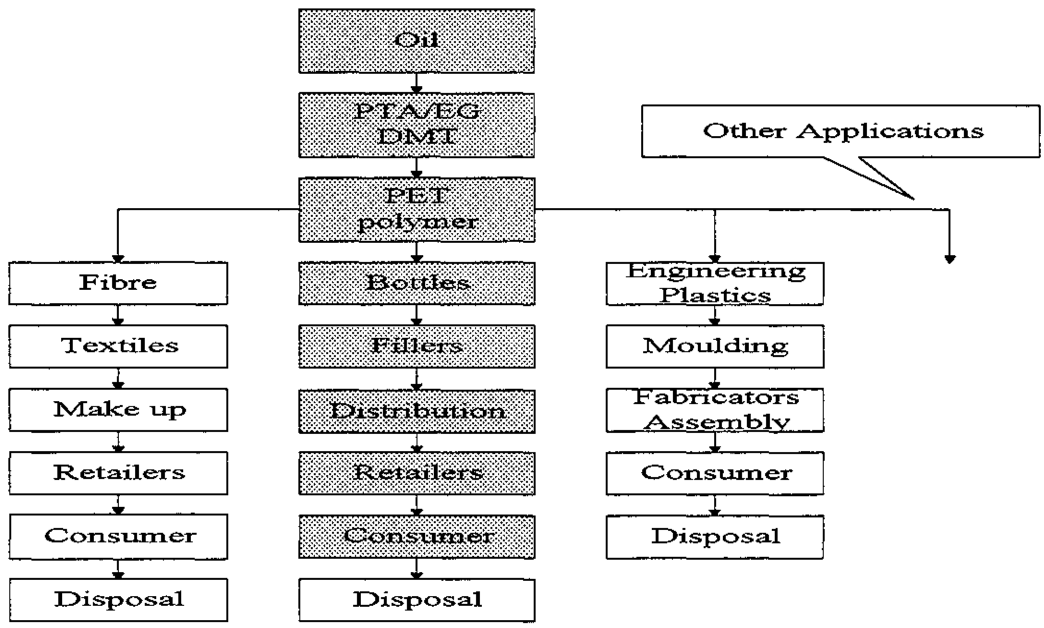
The PET material use chain

The simplified diagram (Figure 4) illustrates the manufacture of PET resin from its oil sources in the form of materials flow charts and includes three product lines which consume the PET, fibres, engineering plastics and bottles. Each one of these chains could be expressed individually. Associated with each chain there will be an energy consumption value to make the process work. Calculation of this value is rather complicated and involves addition of the individual energy values from a whole series of contributory operations as represented by the general case (Figure 3). For example, the manufacture of PET polymer alone requires inputs from about 15 major processes (Figure5).

The actual inputs for the calculation of the total energy required for delivery of a filled 1.5 litre PET bottle to the consumer, if one includes materials for caps, labels, glues, seals, secondary packaging, display units and the like can number a hundred or two.

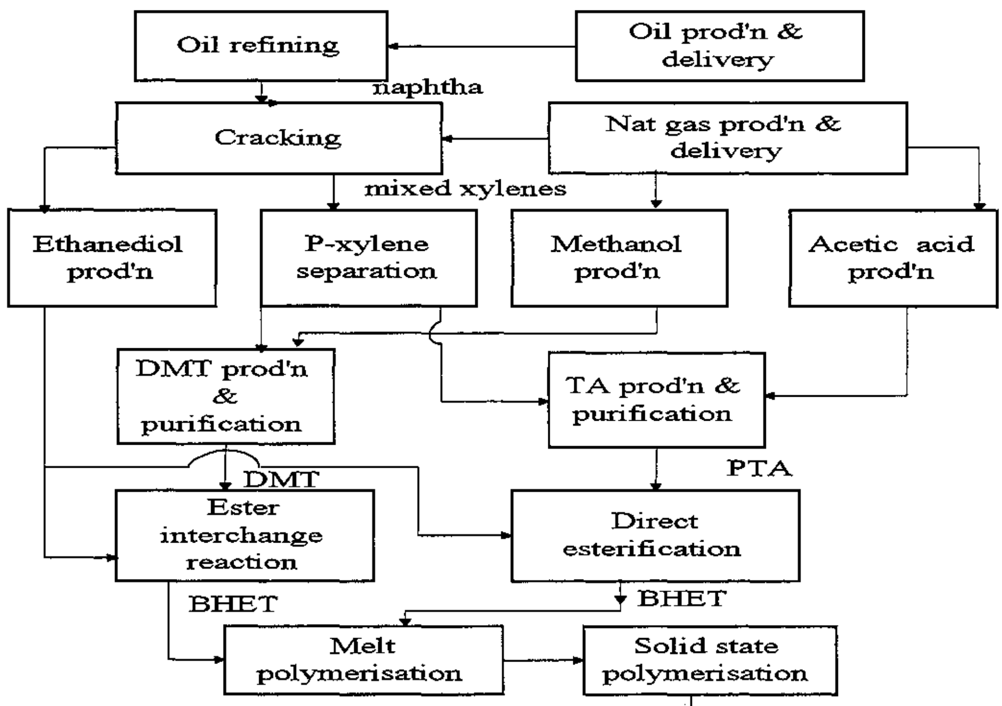
Several studies are now available which have computed the figures for PET containers used in beverage delivery systems. For example, the sequence of operations from oil through to placing a 1.5 litre filled PET bottle on the supermarket shelf totals approximately 18 to 19 MJ per container [1]. The contribution from the oil to polymer material portion is approximately 6 MJ, around one third of the total, two thirds of the energy arising from other sources like filling, outer packaging, transport, bottle manufacture, and other materials.

> ***Note : One MJ will run a 100 watt light bulb for 2.8 hrs, carry a family car for about 0.5 km, boil about 5 litres of water, manufacture about 12 grammes of PET (APME 1995 data)[2] or keep a man in action for 2.5 hrs.***



Typical PET user chains

Figure 4



Flowsheet for PET Production

Figure 5

The systems shown in Figure 5 are the simple linear flow charts without any recycling loops back into the process. Adding a recovery and recycling process into this sequence will make the picture more complex - for simplicity only the recovery of material from bottles is illustrated (Figure 6).

Which is the most suitable recovery process from an energy viewpoint? Should we just wash, clean and granulate to flake? Or, is it more beneficial to breakdown the PET back to its intermediate chemicals?

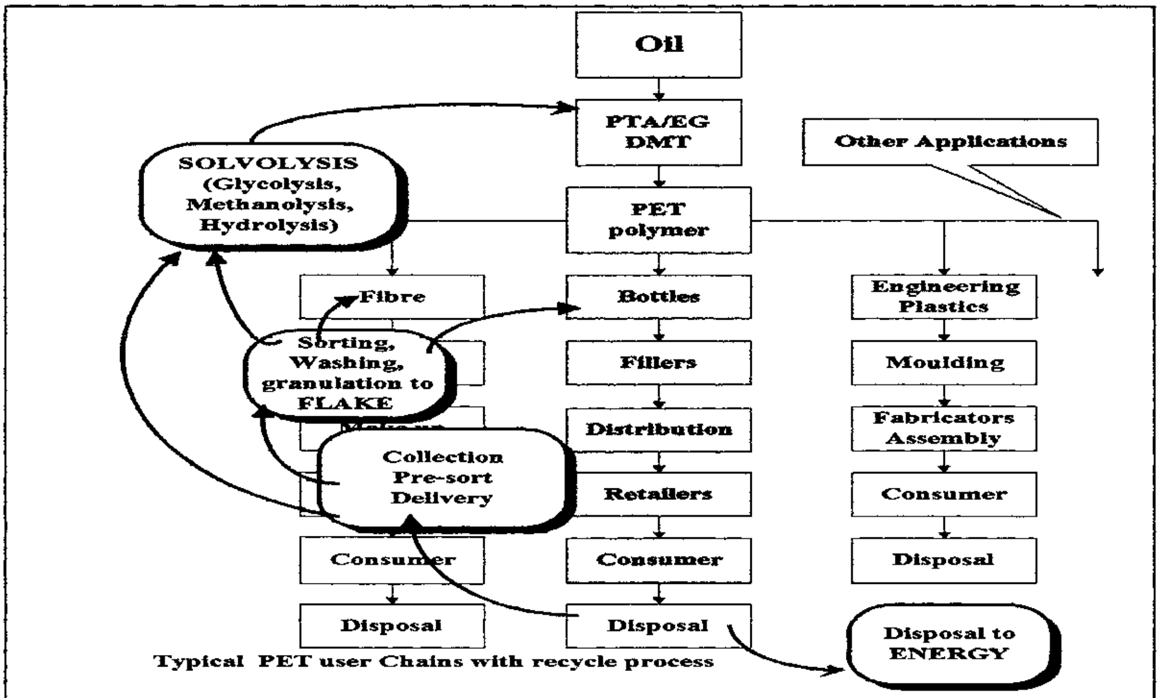


Figure 6

Potential savings from recycling operations

Before one can consider the reprocessing options it is appropriate to look at what savings are possible. In principle collection, reprocessing and reintroduction of recycled PET material will directly displace virgin materials from the consumption chain. It is this displacement value which is the driving force for recycling operations.

The sequence of operations outlined in Figure 5 consumes a total of 84 MJ (*range 66 to 98 APME data published 1995*)[2] for every kg of bottle grade PET produced. This total is made up of 48 MJ as 'feedstock' and 38 MJ as fuels used to drive the process. As the feedstock is reused as material in the recycling process it is the 38MJ lost as fuels we need to compare recovery processes against. If this material were not produced the total savings available would be equal to this value. Any PET recovery operation consuming a total energy less than this value should - in theory - contribute a saving of resource.

Note : this value will continue to fall as manufacturing technology improves. In the early 1980's intermediates plant usually had operating capacities of 100,000 to 150,000 tpa. Similar plants installed today will have operating capacities of 250,000 to 400,000 tpa. Similar changes are noted with polymerisation capacity, 150,000 tonne units are in operation today, an advance on older 50,000 tonne capacity plants. These unit size *changes and technology improvements increase efficiencies enormously, especially energy utilisation. It is these factors which have allowed the price of PET to remain virtually unchanged over the last 15 years and reduced the energy consumption to the lower figures we see today.*

Prior to assembling this revised energy data the figures in the public domain calculated for the Figure 5 process were a little variable and certainly old. Historically the sources read approximately as shown below Table 2.

Table 2: Energy values from the literature[1-3]

Boustead - private communication 1982 :	ca 150 MJ/kg
Franklin Associates - 1980	123 to 127 MJ/kg
Boustead - INCPEN 1989 and 1992 reports :	128 to 135 MJ/kg
Franklin Associates - 1992:	89 MJ/kg
BUWAL 132 1990 :	ca 70 MJ/kg
APME - 1995	84 MJ/kg

Collection of bottles

Obviously before we can reprocess we need a supply of collected bottles. The energy associated with collection is very often accounted for in a social context and as part of the duty carried out by local authorities in connection with waste disposal operations. This figure can be extremely variable, however if recycling is being operated to save overall resource energy expended on collection must be factored into the calculations.

One of the best sources of information on energy of collection in recent studies comes from The Netherlands study on plastic waste management options[4]. Five different collection models were studied consuming between 3 and 4 MJ/kg for collection, some pre-treatment separation and delivery to the processing plant,

1. Collect integral with MSW and ship to MSW combustion plant.
2. Kerbside separate collection of 100% of plastics as part of MSW scheme. Transport to separation plant
3. Kerbside collection of 95.9% plastics as in 2. Collect 4.1 % separately as bottles.
4. Kerbside collection of PMD (plastics/metals/drinks cartons).
5. Kerbside collect 54% of all plastics and 46% with MSW. Delivery to feedstock recycling.

Note: the lowest energy option is not to collect, separate, measure the yields and deliver to the recyclers but to collect and deliver straight to an energy recovery facility (ca 1.5 MJ/kg).

This latter figure could be a realistic representation of a very basic minimum value that could be achieved if all that was needed was to collect and prepare 100% PET bottles and deliver to a processing site. These values are probably representative of the better developed schemes. There are schemes at earlier stages of development which reflect higher energy figures. Certainly those with a higher proportion of drop off collection points and rural areas would expect to consume more energy.

Information from studies done for APME[2] calculate collection energies from 0.2 to 1.2 MJ/kg for systems covering collection with MSW to separate green bin collection of all plastic bottles. Rural area collections can be up to 5 or 6 times more energy intensive.

Data[5] suggests collection energy figures of up to 15 MJ/kg (including sorting) and also gives some indication that volumes from urban collections can be up to seven times more effective in yield when compared to collections from rural areas.

These figures suggest that sensible collection schemes for recyclables should be developed which are not too ambitious. Simply setting goals of 80 to 90% recovery when the best available information says less than half of this is achievable are guaranteed to fail. To obtain the correct balance demands careful analysis before compiling a programme. The general diagram (Figure 7) illustrates how the balance will change as a programme becomes more successful and recovery of the last remaining material shifts the 'profitability' of the exercise. Application of Pareto analysis to target the major effects is recommended and a careful audit of both environmental costs in addition to the normal economic cost carried out on a regular basis.

Depending on the type of recycling process used, the reprocessed bottles could be introduced back into the chain either as clean washed polymer flake, as partly polymerised PET (glycolysis) or as the recovered intermediates, dimethyl terephthalate (DMT -from methanolysis), terephthalic acid (PTA) and ethylene glycol (EG) from hydrolytic processes.

Reprocessing of the collected containers can be done in several ways, but the procedures illustrated (Table 3) usually follow the delivery of bottles to the processing plant. For the purposes of this discussion we are only going to consider the methods of recovery back to a reusable polymer.

Table 3: Reprocessing stages to PET

Method of recovery	**Approximate Energy Consumption MJ/kg**	**Reference**
Reprocessing to clean PET flake	6 to 15	1,4,5.
Hydrolytic processes to PET	20 to 30	2, 3.
Methanolysis/glycolysis to PET	40 to 60	4,5.

There is also another option, which should not be ignored for lower quality materials unsuitable for mechanical recycling. PET has an intrinsic energy value equivalent to that of soft coal i.e., 23 MJ/kg, or approximately half that of fuel oils. (Hydrocarbon fuel oils have values of ca 40 to 45 MJ/kg). It does burn in a clean manner and can be used as an effective fuel substitute. If energy recovery is considered, the virgin PET will not be replaced in the user chain but fuel oil will be replaced in a corresponding fuel supply chain. So after subtracting the energy used to deliver to the waste to energy plant (2

MJ/kg) it is possible to recover up to 21 MJ calorific value. Table 4 summarises the potential savings from each of the 'recycling' processes.

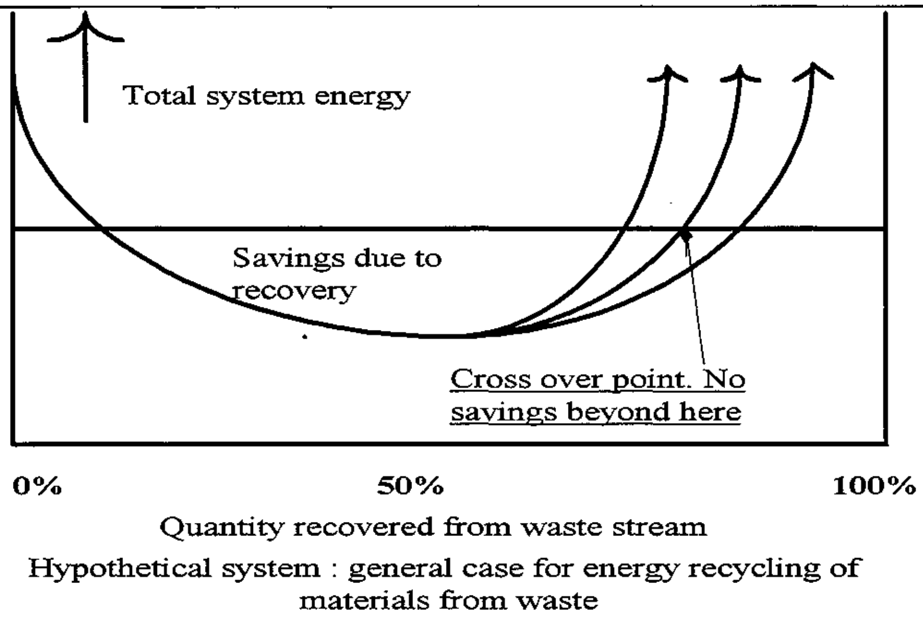


Figure 7

Note. Associated with the description 'a collected PET bottle' are labels, caps residues from the contents and other soil dependent on method of collection and storage. This associated detritus can amount to 50% of the total weight. As bottles are engineered lighter this ratio generally increases. Separation and preparation before final reprocessing can make very variable demands on energy input. This is particularly so with methanolysis and glycolysis. Some hydrolytic processes claim an advantage by being able to use highly contaminated feedstock needing a minimum of pre-treatment. Good quality used PET bottle input is essential for efficient reprocessing.

The conclusions that can be drawn from this 'broadbrush' analysis are that the most effective method of recycling is the simple washing and regeneration of reusable PET flake. Once the recovery processes include remelting or depolymerisation using high temperatures and pressure the energy demands rise markedly. However, it should be stressed that each recovery and reprocessing option should be considered individually. Where there are likely to be special circumstances, e.g., large volumes of very clean used PET sources or the absence of facilities to use the simple remelt route.

Note : The energy value to produce PET resin ranges from 66 to 98 MJ/kg. If 66 MJ/kg is representative of future manufacture the potential savings would be reduced by approximately 18 MJ/kg.

THE CONSUMER FACTOR ?

Usually this factor is ignored in calculating savings, but can have a large influence on overall energy savings. The consumer collects the bottles from the retailer and after using

Table 4: Summary of energy savings (in MJ) from each process

All MJ/kg	Fuel Energy to manufacture virgin PET	Energy for Collection / delivery	Energy for Reprocessing	Energy for Total 'waste management	Potential savings - from displacement of virgin PET
Washing to Flake	38	2 to 15	6 to 15	8 to 30	8 to 30
Hydrolysis	38	2 to 15	20 to 30	22 to 44	16 to (-6)
Glycolysis/ Methanolysis	38	2 to 15	40 to 60	42 to 75	losses (-4) to (-37)
Energy	40 to 45 (Fuel Oil Value only)	2	0	2	19 to 23 (21 MJ reclaimed as fuel)

the contents deliver the empty bottle back to the collection point. If we are serious about saving resource this is also a factor we should examine and include in the equation. The problem with this sector is that the detailed habits of shopping and returns are so variable that accurate analysis is very difficult. However, Boustead[1] notes that 30% of shoppers make the trip on foot, 32% travel 3 miles (ca 5 km & 90 % of these by car) and the remaining 38% travel 7 miles (11 Km). The average car consumes approximately 3 to 3.5 MJ energy/ km. Those good at maths will calculate this is a consumption of approx. 17 to 20 MJ/trip. This energy would of course be averaged over all the contents purchased (ref. 1 suggests 10 items purchased each trip). If the containers are returned on the next shopping trip the energy is consumption is kept to a minimum. However, if the purchase of soft drinks is a singular activity and the return to a drop-off container is also a special trip, the consumer factor can very rapidly make recycling an irrelevance as far as overall environmental benefit is concerned.

The consumer should be encouraged to combine the purchase and drop off together with other trips if energy consumption is to be minimised.

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TOWARDS ENVIRONMENTALLY RESPONSIBLE DESIGN IN TEXTILES

Kate Fletcher

INTRODUCTION

Design generates products, services and lifestyles. Its activities dictate the environmental compatibility of the products and services we consume both individually and as a whole in society. In order to make changes to achieve more responsible patterns of production and consumption, environmental considerations have to be addressed more actively in design. This paper explores how the effective use of design can contribute to the development of more environmentally responsible practice in textiles. It investigates the role that design can play in bringing more resource efficient textile products, looking specifically at products with a longer life and it examines how design can contribute towards the goal of sustainable development.

The terms 'design' and 'designer' are frequently used in many different contexts and definitions can cause confusion. For the purpose of this paper however, it is assumed that design is the process whereby an initial product idea is conceived and then translated it into tangible combinations of materials and process specifications; and that the designer is the person who puts this into practice. It should be acknowledged that designers operate in many different ways as part of many different design processes, each having differing degrees of autonomy and influence over the product and the product development process. These can range from the designer based in an organisation's design department who has some influence over product development, to the designer as independent consultant or the designer working at an isolated stage in the production process, who has very little control.

DESIGN AND THE ENVIRONMENT

Design's ability to influence the environmental profile of goods and services was acknowledged by the Brundtland Report [1]. Best known for its popularisation of the term 'sustainable development', the report also made recommendations for a new approach to design and production, setting out terms for: 'a production system that respects... the ecological base' and, 'a technological system that searches continuously for new solutions' (ref.1, p65).

Design has a principal role to play in developing these 'new solutions'. It is estimated that eighty percent of a product's environmental and economic costs are committed by the final design stage, before production begins [2]. Therefore by integrating environmental considerations into design, there is potential to bring far-reaching environmental benefits. For design to be most effective, ecological considerations have to be built into the earliest stage of product conceptualisation and design development. This has the effect of preventing environmental impacts, so minimising the need for 'clean-up' remedial action further down the chain. This, according to Keoleian and Menerey [3], makes design: 'the most proactive direct action one can take to achieve (impact) prevention'. It is common however, for both design and the environment to be consulted after initial product development; for design to be viewed by industry as an 'add-on extra', tacked onto the end of the development process. Using design in a reactive way brings lower level environmental benefits. Designers are limited to manipulating materials and components already specified at an earlier stage in product development.

In the textile sector, designers have traditionally been seen to be concerned primarily with product styling and to be inexperienced about technical elements of production and associated environmental impacts. Research documented by Heeley [4], reveals a number of structural and educational reasons why textile designers rarely engage in, and offer solutions to, the environmental debate. The conclusions show that designers are blocked from developing more responsible practice by a role that allows them too little time, knowledge or control over materials and processes; and, by design training, whose chief focus is 'task' and not technical or contextual issues such as the environment. Indeed, the actual act of design is commonly seen to exclude considerations such as the environment, it is seen instead as a, 'self-sufficient and self-justifying activity... not in need of any external knowledge. It encourages students in their own stylistic development... without a matching critical concern for meaning' [5,6].

Factor 20 reductions

It is vital that organisations re-examine their position towards design and that textile designers develop new skills so that they can engage with the challenges and opportunities that environmental impact reduction demands. The overall scale of impact reduction necessary to maintain environmental impacts at their current level, given that world population is set to double in the next forty years, is predicted to lie between a factor of four and a factor of 20. Initiated by population experts [6], the concept of 'factor 20 reductions' has since been adapted to illustrate the enormity of the task ahead of design. In essence it states that in order to contain pollution levels as consumption increases, the environmental impact of products and services will have to be reduced by 95 percent, or to one twentieth, of today's level.

Today, the most common approach to managing environmental impact reduction involves repairing environmental damage after it has occurred. Cleaning up pollution end-of-pipe and recycling waste brings limited environmental benefits (see Figure 1). Greater benefits can be achieved by adapting existing products and processes, refining them so they are more resource efficient. However to achieve improvements in environmental quality of the order that Ehrlich and Ehrlich propose (i.e. a factor of 20), radical changes need to be made. Products, services and entire systems have to be redesigned and patterns of production and consumption fundamentally reassessed.

The lifecycle

The basic concept underlying the ecological approach to design is the lifecycle. It involves connecting the design of a product to the larger situation of materials extraction, production, use and disposal and attempts to minimise environmental impact across this entire lifecycle. Prioritising impact reduction of the whole system, rather than concentrating on impact reduction of certain process stages, prevents shifting pollutants between air, land and water or between different lifecycle stages [7].

The design of products and of the processes needed to make them has traditionally been two separate and consecutive activities. In direct contrast, the lifecycle approach is less linear and relies on design to constantly analyse and re-evaluate the product in the light of environmental constraints in production, use and disposal. This means that waste, for

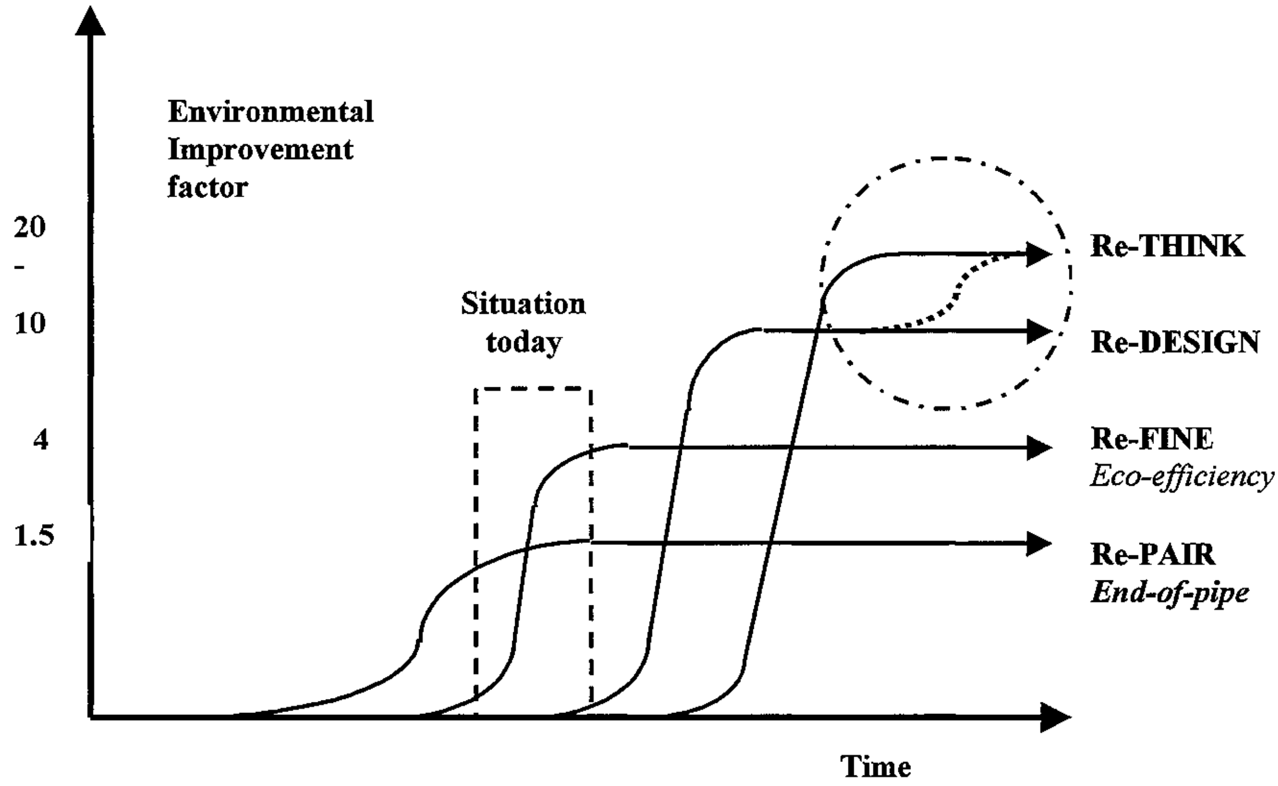

Figure 1: Four steps of environmental improvement

example, is not only an 'end of life' environmental problem, but is instead a 'lifecycle' problem [8] and planning to reduce environmental impact at the end of a product's life is as integral to the product development process as reducing emissions in processing. In order to focus on impact reduction across the entire lifecycle, the designer has to be employed in a strategic role. This involves product conceptualisation, planning and manufacture as well as envisaging strategies of use and disposal. In order to make strategic lifecycle design decisions, the designer has to understand and have access to technical information and be supported by communication channels which allow knowledge about environmental problems to be fed back to those responsible for input considerations.

Rather than taking account of the whole system, the environmental approach of the textile industry is typified by attempts to optimise the environmental efficiency of isolated stages in the production chain. This approach however, is a reaction to the focus of most current legislation on *process improvement* which, for example, concentrates on controlling certain process chemicals and encourages end-of-pipe clean up. Recent legislative developments, such as producer responsibility and product 'take back' schemes extend the role of the producer beyond manufacturing, promoting the entire lifecycle. Take back legislation obliges manufacturers to take back their used product and then dispose of it. Pressure from such schemes and high disposal costs have led producers to analyse the ways in which valuable materials can be reclaimed and the benefits of designing products with an extended life. In Germany such legislation is forcing carpet manufacturers to investigate design strategies for materials reuse.

ECO-EFFICIENCY

To date, most design activity concerned with environmental criteria has focused on rationalising existing products and is often referred to as 'eco-efficiency'. The World Business Council for Sustainable Development define eco-efficiency in terms of adding maximum value with minimum resource use and minimum pollution [9]. Eco-efficiency involves streamlining current operations in environmental terms: reducing resource inputs, waste and emissions and maximising energy efficiency.

Developing more eco-efficient products and services involves the substitution of less damaging materials for more hazardous ones; the development of more resource efficient products which can be maintained and upgraded easily; and, the selection of materials which can be more easily reclaimed and reused (see Figure 2). Many design guidelines developed for environmentally responsible products have their antecedence in good design practice. Notions such as durability and materials efficiency have, for example, always been central to good design.

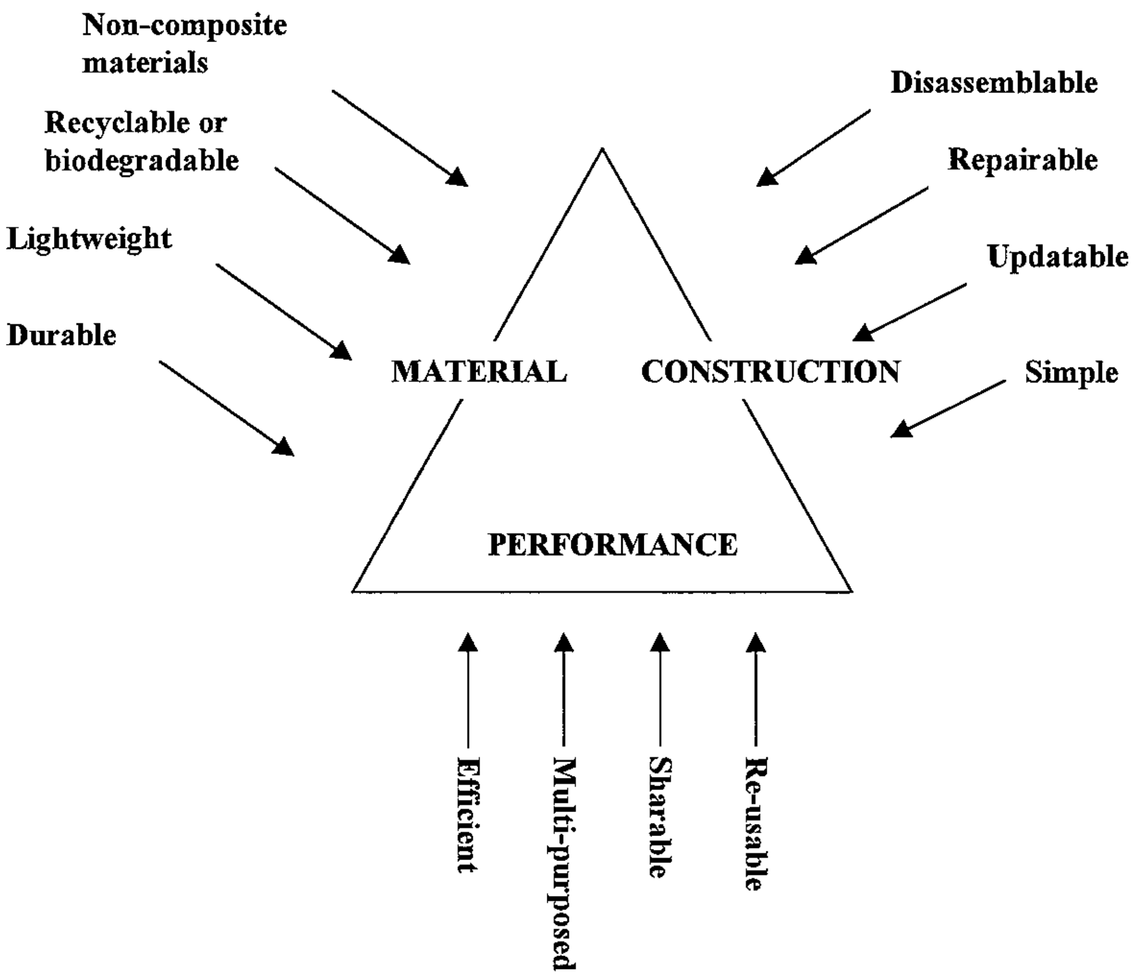

Figure 2: Design guidelines for environmentally responsible products

Longer life products

One much investigated strategy for reducing resource use and environmental impacts through design, is the development of longer life products. Product life extension reduces impacts and conserves resources because fewer units are consumed to meet the same needs. Tim Cooper [10], who has written extensively about the development of longer life products, stresses the environmental benefits that extending product life brings, especially in the context of waste reduction. He acknowledges the complex economic and societal resistance to introducing longer life products, highlighting the dependency of economic growth on a throwaway culture in which the buying of replacement products gives momentum to the economy.

Designs which simply make a product last do not necessarily bring environmental improvements. A product's durability should only be increased when appropriate, as resources can be wasted if a design specifies materials which outlast the product. Rather than designing for maximum durability, it is important that materials and components are appropriately durable, i.e. they have a life which matches the product's expected useful life. If, for technological or fashion reasons a product is expected to become quickly obsolete, then it is preferable to design a product which is upgradable or easily adapted for another use, rather than design it for durability [3].

For products which quickly become obsolete, it is not only an inefficient use of resources to design them for longevity but it is also inefficient to design them from high quality materials. For products with a short life, less resource-intensive materials should be specified. Medical textiles, for example, which are used once and then thrown away are frequently made from resource efficient nonwoven materials. Fashion fabrics quickly become obsolete and yet are often made from long life materials. Environmental benefits could be gained by matching a fabric's resource intensiveness and its durability to its expected useful life.

When products have a long useful life, materials should again be appropriately durable. For long life products it is crucial that materials have the ability to withstand wear and tear. A recent Dutch research project, *Eternally Yours* [11] has investigated strategies for product endurance, looking at approaches to designing products for longevity, investigating wear as a design feature as well as studying consumer/product interaction. In long life products the user is especially important, playing an active role in the product lifecycle through maintenance and use, rather than being purely a passive consumer. The development of durable textile fabrics which capitalise on surface wear, using it as a feature and engage the user in the ageing process have a positive influence on reducing waste.

Design-led improvements in the environmental efficiency of products and services reduce resource consumption. Yet this has to be balanced against business demands to improve profits through increased sales, involving greater consumption of resources. In order to have a net improvement in environmental quality, resource efficiency has to increase faster than economic growth. The pressure therefore, is not just to optimise existing systems because this has limits, but instead to rethink them completely.

SUSTAINABLE DEVELOPMENT AND DESIGN

Sustainable development is a complex of social, economic and environmental dimensions. Design strategies that contribute towards the goal of sustainable development have to take into account issues of equity, resource use and environmental impact. Such strategies are, 'rethinking priorities and changing fundamental attitudes including phasing out unnecessary products (and) reversing the process whereby luxuries are turned into needs' [12]. The design of a more sustainable system requires an approach more fundamental than the development of eco-efficient products and processes.

Improving the environmental compatibility of goods and services requires high levels of compliance from all sectors of society: industry, finance, government, education and perhaps most crucially, it requires a shift in societal values and behaviour. On a design level, this shift will involve a switch to thinking about systems optimisation instead of product optimisation. Rather than concentrating on developing eco-efficient products, needs will be met in new ways. One of these new approaches is to concentrate on functional needs. Products perform a function. In the case of televisions for example, it is the provision of entertainment and information, and for cars, mobility. Yet industry does not supply these 'functional units' of entertainment or mobility, instead it sells the material good - the microchips, the black plastic casing, the fuel injected engine. Switching the system around to concentrate on the supply of functional units rather than selling material products allows a complete reassessment of the financial and environmental efficiency of production and consumption.

The American carpet company Interface, for example, have started to deliver a service based on functional units. They supply their customers with colour, texture, warmth, acoustics and underfoot comfort by leasing them floor tiles. Interface retain ownership of the carpet, replace it when it is worn and reclaim the old carpet, recycling it into valuable raw materials. Such an approach transforms the traditional business incentive to increase sales by encouraging early product obsolescence into an incentive for product durability and efficient use of materials [6]. The environmental responsibility of this new system is higher and profitability is no longer based on selling more products. Design takes a prominent role in determining the system's success. Without a carpet that is designed for durability and to be easy of recycle the system would founder.

CONCLUSIONS

This paper has explored how environmental impacts can be reduced, and resources conserved, through the effective use of design. The ecological approach to design is grounded in the concept of the lifecycle. It involves connecting the design of a product to the larger situation of materials extraction, production, use and disposal and involves reducing the environmental impact of the whole system.

Since design is responsible for 80 percent of a product's costs including environmental impact, environmentally responsible design strategies have the potential to bring far-reaching environmental benefits. However in order for design to be most effective, ecological considerations have to be built-in at the first stage of product conceptualisation and design development, with the designer operating in a strategic role. In the textile sector, a combination of structural and educational barriers are blocking the use of environmentally responsible design as a preventive course of impact reduction.

A popular strategy for reducing environmental impacts through design is the development of longer life products. Rather than designing products to simply be durable, it is important to develop appropriately durable products, that is to match a product's durability with its expected useful life. Both short and long life fabrics which are designed from appropriately lasting materials save valuable resources.

Design strategies which lead towards sustainable development have to take into account issues of equity, resource use and environmental impact. They demand a radical reassessment of production systems and a reorganisation of consumer behaviour. It also requires an approach to design which questions the validity of existing products and investigates new ways in which needs can be met. This includes, for example, meeting society's functional needs in a new, more resource efficient way Thus in the development of new solutions for a more sustainable society, design has a pivotal role to play. This is underlined by design writer Manzini [13] who states that, 'Designers are able to give shape to a changed world and to advance solutions that offer a chance to learn and adapt to a new lifestyle'. Let us plan this new lifestyle to be sustainable.

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IMPACT OF ENVIRONMENTAL AND COMMERCIAL PRESSURES ON DYE USE

BC Burdett

INTRODUCTION

In terms of production and employment, the textile industry is one of the largest industries on a global basis. Operations typically vary in scale from large mechanised plants to small traditional units. All are characterised by the consumption of large quantities of water and energy, and of a large range of chemicals used in a complex processing chain based on multi-stage processes. The latter convert raw materials into intermediate and final products, which ultimately have an impact on consumer awareness. Unwanted emissions and by-products sometimes accompany this conversion.

Historically, the textile industry, like many manufacturing industries, has been accused of reacting unwillingly to environmental legislation or even ignoring environmental consequences of its processes. However, there is increasing evidence that the industry and the consumer are concerned with long term environmental issues.

Knowledge of the effect of the processes carried out by the textile industry on the environment has been gaining ground, and there has been a growing trend on behalf of the general public of the need for environmental protection. There is increasing emphasis on, for example, the production environment, industrial and urban waste, air pollution, water quality, and use of pesticides, environmental management, and clean technologies. Within the textile sector the philosophy is to improve processes along the entire production chain from raw material to final product.

There is now an emphasis on 'lean processing', which in turn requires the use of environmentally friendly process technologies and the organisational requirements for introducing them [1]. Markets for environmentally sound products provide an incentive for companies since they are an added source of profit; it is becoming increasingly acknowledged, that ecological optimisation could also result in economic advantages. The 'eco industry' is now widely accepted as an expanding industrial market, and will continue to expand into the foreseeable future.

The effect of dyes on the environment needs to be taken more and more seriously. Recent developments in 'eco-label' schemes such as Öko-Tex, GuT and EU [2,3] provide an indicator to the next century, when environmental changes will be driven by consumers as much as legislators.

The main issues are, the toxicity of the dyes themselves, specific restrictions on the use of dyes which could break down to MAK amines, the use of heavy metal ions in dye structures and in dye synthesis, and modifications in the application technologies to reduce the quantity of chemicals necessary to apply, and to fix dyes to textile substrates. The challenge for the innovators is to develop dyes and application technologies, which will anticipate the demands of the legislators and consumers.

Environmental pressures have increased during the past few years; it can be predicted with certainty that this pressure will increase further into the next century. We require technologies with minimal environmental impact, and innovative solutions to environmental problems [4].

ECOLABELS

Ecolabelling is a philosophy and way of life that is increasing in importance in Europe, and indeed on other Continents, and it is having an effect on application technology through out the textile chain. Consumer Associations insist on positive declarations on ecolabels, particularly for textile materials, and on substances used on fabrics or garments. Use of chemicals, including dyes, during manufacture and their retention by textile materials is important in relation to human ecology. Questions are asked as to the possible harmful effects of the final merchandise, particularly clothing, on the human body, and on life-cycle analysis of the product, the so-called 'cradle to grave' approach. In the schemes now in effect or under discussion, certain chemicals are not to be detected while others may be present below certain defined levels of concentration.

Within Europe there are many ecolabels, some are national, whereas others are pan-European [2,3]; it is the latter that this paper will concentrate on.

Öko-Tex Ecolabel

Probably the most widely used textile ecolabel is the 'Öko-Tex Standard 100', the label of 'the International Association for Research and Testing in the Field of Textile Ecology', for which there are 13 test institutes located throughout Europe currently carrying out the approved test protocol. The Öko-Tex Standard 100 mark states that the textile product or accessory has been tested for harmful substances according to the conditions specified in this standard. The standard is applicable to textile and leather products and all levels of production, including textile and non-textile accessories. The objective is to market clothing and other textile products, which do not contain substances detrimental to health. There are four product groups, classified by their contact with the human skin, namely,

Product Class I: *Products for babies*
In this context the products are articles for babies and children up to the age of two years old with the exception of leather clothing.

Product Class II: *Products having direct skin contact*
Skin contact articles are those, which are worn with part of or all their surface in direct contact with the skin, e.g. blouses, shirts, underwear.

Product Class III: *Products not having direct skin contact*
These are articles, which are worn with only a small part of or none of their surface in direct contact with the skin, e.g. skirts, trousers, and jackets.

Product Class IV *Furnishing and decoration material*
This group contains furnishing and decorative materials such as table linen, decorative textiles and curtains, furniture fabrics, textile floor coverings and mattresses.

One of the main features of the scheme is the test procedure for chemicals associated with dyeing processes and for dyes themselves. Thus, for all of these product groups there are limiting values placed on extractable heavy metals (Table 1). Extractable in this context means the metal must be extractable with artificial acid perspiration, or saliva for Product Class I. The limiting values on extractable heavy metals affects the use of dyes, because of metal contamination (perhaps from the catalysts used in dye synthesis) and the use of formal ligand structures, particularly

Table 1: Limiting values for extractable heavy metals (ppm)

Metal	Class I	Classes II - IV
Arsenic	0.2	1.0
Lead	0.2	1.0
Cadmium	0.1	0.1
Chromium	1.0	2.0
Chromium VI	not to be detected	
Cobalt	1.0	4.0
Copper	25.0	50.0
Nickel	1.0	4.0
Mercury	0.02	0.02

Table 2: Carcinogenic arylamines

MAK III A1	Benzidine	
	4-Chloro-2-methylaniline	
	2-Naphthylamine	
	4-Aminobiphenyl	
MAK III A2	3,3'-Dimethylbenzidine	3,3'-Dimethoxybenzidine
	3,3'-Dichlorobenzidine	4-Chloroaniline
	o-Toluidine	o-Anisidine
	o-Aminoazotoluene	2-Amino-4-nitrotoluene
	2,4-Diaminotoluene	2,4-Diaminoanisole
	4,4'-Diaminodiphenylmethane	
	4,4'-Diamino-3,3'-dimethyldiphenylmethane	
	4,4'-Methylene-bis-2-chloroaniline	4,4'-Oxydianiline
	4,4'-Thiodianiline	2,4,5-Trimethylaniline
	p-Cresidine	

those based on chromium VI. This does not preclude the use of metal-complex dyes as long as the complex is stable to the extraction process. Chrome dyes may be used on wool merchandise as long as all residues of the dichromate are washed off. In addition, there is a ban on the use of dyes that reductively split to produce carcinogenic arylamines (MAK amines Class III A1 and III A2 derived from certain azo dyes) (Table 2), or dyes that according to the present state of the art are classified as carcinogenic (Table 3) or classified as allergenic (Table 4).

Dyes feature very prominently in the Öko-Tex scheme; within the group of test institutes, of which BTTG is one, there is a database of over 1,500 dyes, which have been tested and are therefore known to be acceptable or not. The extent to which the metal content falls within the specified limits can depend on the amount of dye present; experience has shown that the deeper shades pose more problems, due to metal content and, in some cases, lack of fixation.

Table 3: Dyes classified as carcinogenic

C.I. Basic Red 9
C.I. Disperse Blue 1
C.I. Acid Red 26

Table 4: Dyes classified as allergenic

C.I. Disperse Blue 1, 3, 7, 26, 35, 102, 106 & 124
C.I. Disperse Yellow 1, 3, 9, 39 & 49
C.I. Disperse Orange 1, 3, 37 & 76
C.I. Disperse Red 1, 11 & 17
Dyes must not be detected (Detection limit of 0.006% using TLC techniques)

Dyes feature very prominently in the Öko-Tex scheme; within the group of test institutes, of which BTTG is one, there is a database of over 1,500 dyes, which have been tested and are therefore known to be acceptable or not. The extent to which the metal content falls within the specified limits can depend on the amount of dye present; experience has shown that the deeper shades pose more problems, due to metal content and, in some cases, lack of fixation.

In many cases companies that have implemented the standard have introduced improvements in their production procedures, such as a change to more environmentally friendly dyeing processes.

GuT Eco-label

Similar restrictions on the use of dyes and metals on carpets and other floor coverings are imposed by the GuT, the Association for Environmentally Friendly Carpets. The objectives of the GuT scheme are:

- to provide products that are manufactured in an environmentally compatible manner;
- to promote consumer welfare; and
- to optimise the life cycle of the product.

Within the scheme emphasis is placed not only on testing the carpet product, but also on the site of manufacture and, of no less importance, the whole life cycle, including disposal.

As with the Öko-Tex scheme, a ban is imposed on azo dyes that reductively breakdown to MAK amines, which are carcinogenic. Metal-containing chemicals, including metal-complex dyes, which are commonly used in the carpet industry, have been closely scrutinised. In certain circumstances the heavy metal content of residual liquors could give rise to environmental problems, and the metal content of the carpet product could cause difficulties in the recycling or the incineration of the waste. It should be appreciated that throughout Europe about 900 million square metres (1.5 million tonnes) of textile floor coverings are discarded every year; with landfill costs averaging £120 per tonne of waste and continuing to rise, GuT members are increasingly concerned with the problem of disposal.

Despite persistent technical difficulties, GuT members have voluntarily banned the use of dyes and auxiliary chemicals that contain lead, cadmium, mercury or chromium-VI. The vast majority of metal-complex dyes are chromium-VI ligands; thus acid dyes must be more widely used. In turn the decision means that there will be increased production costs and, in some instances, restrictions to the colour gamut and fastness, particularly in regard to light and shampooing. In certain instances problems will occur, for example in rooms with high light intensity or intense ultraviolet radiation.

Chromium in aqueous discharges is increasingly viewed as a severe environmental problem and draft regulations indicate that very little chrome, < 100 ppb, in dyehouse effluents will be tolerated [5]. The environmental quality standard states chromium VI as 5 - 50 micro grams per litre. An important group of dyes, the chrome dyes for wool, are applied in the presence of dichromate; they are important because of their extraordinary fastness properties and economy, particularly in full shades of navy and black.

It is for these reasons that intensive research work is underway to replace the toxic dichromate with fibre substantive chromium-III organic acid, anionic complexes [5]. If successful, we shall be able to continue to use these valuable dyes.

There has been a call to re-appraise the ubiquitous nature of metal-complexing compounds, including dyes [6]. Concern is being expressed with the accumulation of ligands in the environment, particularly since they are not universally biodegradable.

The EU Eco-label

The European Community launched its official ecological labelling policy in March 1992. This policy is based on the product's impact on the environment during its entire life cycle, otherwise referred to as the "cradle-to-grave" approach. Emphasis on life cycle analysis of a product is a significant feature of the scheme. It is a commitment to the welfare of the environment and can be summarised by its objectives, namely:

- to promote the design, marketing and use of products that have a reduced environmental impact during their entire life cycle, and
- to provide consumers with better information on the environmental impact of the products without, however, compromising product or worker safety or significantly affecting the properties, which make a product, fit for use.

As far as the textile sector is concerned, criteria have been adopted for two pilot scale products, namely T-shirts and bed linen manufactured from cotton or cotton-polyester blends.

As with the other labels, there are restrictions on the levels of ionic metal impurities in dyes for 10 metals (Table 5). Further, metal-complex dyes based on arsenic, cadmium, chromium, mercury, nickel, lead, tin, zinc or copper are banned. Copper complexes, however, are allowed on knitted products. There is a ban on the use of dyes, which can release or be cleaved to carcinogenic aromatic amines, or are themselves classified as carcinogenic.

Table 5: Limiting values for metal impurities in dyes (ppm)

Arsenic	50	Cadmium	20
Chromium	100	Copper	250
Mercury	4	Nickel	200
Lead	100	Antimony	50
Tin	250	Zinc	1,500

ENVIRONMENTAL PROCESSING

Although we have seen a change in approach to the choice of dyes brought about by ecolabels, an equally significant driving force is that of the philosophy of 'right-first-time' or 'controlled coloration' [7-10]. These effects are not mutually exclusive. In order to be competitive a high level of right-first-time production is necessary while minimising environmental pollution at the same time. The essential feature for the implementation of controlled coloration is in dye selection. This is necessary to achieve response to the desired technological target, whether it is the use of smaller quantities of electrolyte or to reduce sensitivity to small processing variables when the dyes are used in admixture. In other words, production can be made more environmentally acceptable if there is closer attention to dyes as individual chemicals instead of the traditional emphasis on dye groups.

Reactive Dyes

In a dyeing process the major environmental impact of reactive dyes occurs in the application stage as well as in the washing off stage. Reduction in unfixed dye would diminish dramatically the environmental impact [11]. However, the importance of the use of reactive dyes for the coloration of cellulosic fibres and cellulosic blends cannot be denied, neither can their contribution to the problem of effluent control [5]. From an environmental point of view reactive dyes have come under increasing pressure not only because of low fixation but also because of the use of large quantities of salt (Table 6) [12]. When dyeing cellulosic fibres with anionic reactive dyes, large quantities of an inorganic salt, sodium chloride or sodium sulphate, are require to suppress the negative charge at the fibre surface, which occurs at the high pH values used. The high salt concentrations are necessary to achieve transfer of dye from the aqueous phase to the fibre phase for the build up of the required depth of shade. After dye application processing time must then be used to remove the salt in order to subsequently remove unfixed dye.

Dye manufacturers are offering multifunctional reactive dyes to secure higher fixation and at the same time lower effluent pollution, and dyes whose application require less salt. For example,

Remazol EF dyes from DyStar,
Cibacron LS dyes from Ciba, and
Sumifix Supra dyes from LJ Specialities by the LET'S method.

Here, EF stands for 'environmentally friendly', LS for 'low salt', and in LET'S, L means Low salt, E even dyeing, T time saving, and S save costs.

Table 6: Salt requirement of various dye classes (g/l)

Reactive	up to	90
Direct		15
Vat		20
Acid		5
Disperse		nil

Table 7: Robustness to recipe variables for Procion Yellow PX-R 40 liquid/mercerised cotton

Relative Strength	Urea g/kg	Bicarbonate g/kg
31	0	25
32	0	40
34	50	25
37	100	25
33	150	25
33	200	30

Data extracted from ref. 13.

The dyes recommended for application to unmercerised or mercerised cotton require only from 30% to 50% of the salt used in conventional methods [12]. The dyes recommended for the LET'S method also show low sensitivity to variations in the salt concentration.

Alternatively, the chemistry of the reaction can be modified. For example, if nucleophilic amino residues are incorporated into the fibre in place of lower reactive hydroxyl groups then the fibres could be dyed at a pH value of 7 and in the absence of salt; high colour yields with high fixation would occur [5].

In their use in printing urea and alkali (either as sodium carbonate or bicarbonate) are important components of the print paste. However there is an increasing demand to reduce the quantity of urea in the paste in order to reduce the nitrogen load. By carrying out variation tests with dyes such as the one illustrated in Table 7 it can be shown that the amount of urea used generally in a print works is in excess of that required to achieve optimum fixation [13]. Dyes that show a high safety factor in relation to alkali/urea variations can be examined with confidence for urea reduction technologies. Ciba states a similar characteristic of a dramatic reduction in urea, the "urea requirement", for the Cibacron P dyes [14].

Disperse Dyes

Disperse dyes are not without their problems. After application to polyester fibres, loose disperse dye on the fibre surfaces is removed by reduction clearing with sodium hydrosulphite and sodium hydroxide, which increases costs as well as the overall time of the process. Reduction clearing is necessary to avoid staining of cellulosic components in the dyeing of blends, and to achieve satisfactory wash fastness in subsequent domestic washing, which is the most important fastness criterion. The requirements of easy or no reduction clearing and high fastness have been achieved with the use of new chemistry, such as azo thiophene and benzodifuranone chromophores [4,11]. The introduction of the subsequent Dispersol XF and Dispersol SF dyes of BASF, formally from Zeneca, have lead to the avoidance of reduction clearing and high wash fastness with all the cost and environmental benefits.

CONCLUSION

Environmental, legislative and commercial pressures are dictating the choice of dyes and their methods of application ever increasingly. Commercial pressures are providing the impetus for 'right-first-time' or 'controlled coloration' procedures. The more efficient use of dyes not only has an impact on reduced dye wastage, but also on more efficient use of other chemicals. In certain cases the need to use auxiliary chemicals is virtually eliminated. The introduction of ecolabels provide an indication to the future that environmental requirements will lead to innovation in dye manufacture as well as to dye application.

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DYES AND MICROBES; COLOURATION OR DECOLOURATION?

David S Wales, Debra K Hobson and Nicola J Willmott

INTRODUCTION

The first synthetic dye, mauveine, was prepared by Perkins in 1856[1]. Thus the demise of the use of natural dyes, which had dominated world markets, began, as the demand for colorants could not be satisfied in terms of either volume or performance by natural dyestuffs[2]. With the advent of synthetic dyes, so came environmental problems associated with both their production and use. Perversely, biotechnology offers solutions to the clean synthesis of anthraquinone based dyes, and the treatment of dye containing effluent.

Colouration

Anthraquinone dyes are at present on the decline. This decline, essentially, is not a result of any shortcomings of these compounds as dyes, but chiefly because their chemical synthesis is expensive[3]. The process of anthraquinone production is costly from a waste disposal point of view; waste products include strong acid, chromium, vanadium and mercuric salts, plus a variety of ill defined organic and inorganic impurities[4], all of which have to be safely disposed of without contaminating the environment. Nevertheless, anthraquinone dyes have important properties of chemical stability, light fastness and brightness which are difficult to attain with other structures.

Simple hydroxylated anthraquinones are known to be produced by microorganisms. Therefore, the production of such anthraquinones by fermentation would be a more environmentally clean method of generating anthraquinone dyestuff intermediates. Anthraquinones of the disperse class are generally simple structures whose production would require only moderate modification of the naturally produced anthraquinone.

Decolouration

The discharge of coloured waste waters from textile dyehouses, in the past, has prompted more complaints to the water companies than any other form of pollution. Brightly coloured water-soluble reactive dyes and acid dyes are particularly problematic, passing unaffected through conventional treatment systems at the sewage works and entering water courses.

Many synthetic dyes, such as azo dyes, are resistant to microbial degradation under the aerobic conditions normally found in wastewater treatment plants since dyestuffs are designed to be resistant to chemical fading and light-induced oxidative fading[5]. Other factors involved in reducing the biodegradation of dyes include properties such as high water solubility and high molecular weight, which inhibit permeation through biological cell membranes. Many dyestuffs, in particular disperse, direct dyes and basic dyes, are expected to be removed from waste waters via adsorption on to activated sludge[6]. Acid dyes and reactive dyes, however, exhibit low adsorption values and, thus, pass through activated sludge processes largely unaffected (see Table 1).

Table 1: Adsorption of dyes on to activated sludge

Dye Type	Adsorption characteristics
Acid	Highly water-soluble. Poor adsorption
Reactive	Highly water-soluble. Poor adsorption, unrelated to number of $-SO_3H$ groups or ease of hydrolysis
Direct	High level of adsorption
Disperse	High to medium level of adsorption
Basic	High adsorption

However, bacterial degradation of reactive dyes does occur under anoxic or anaerobic conditions, and offers a solution to the clean up of effluent containing such dyes that are difficult to remove by conventional methods.

NATURAL ANTHRAQUINONES AS DYESTUFF INTERMEDIATES

At the beginning of the nineteenth century, natural dyes dominated the world market. Natural yellows such as Quercitron were of low tinctorial strength and had poor fastness properties, and therefore have been completely superseded by synthetic yellow chromogens. However, the natural anthraquinone and indigoid chromogens found in natural red (e.g. Cochineal) and blue (e.g. Woad) dyes still form the basis of many modern synthetic dyes, especially the anthraquinone derivatives (Figure 1).

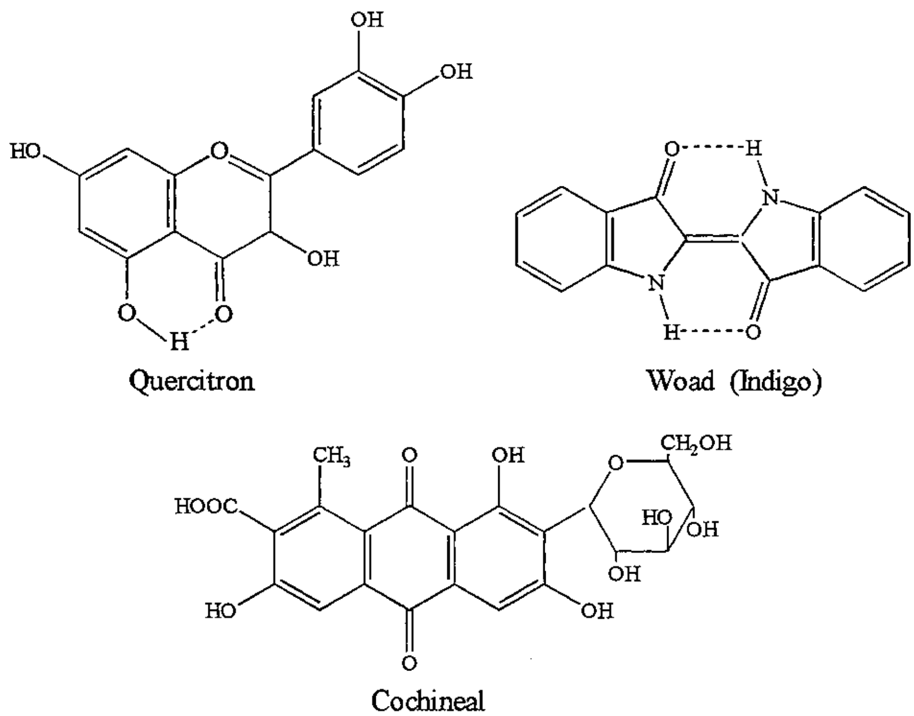

Figure 1: Natural Dyes

Anthraquinones occur widely as secondary metabolites produced by many genera of fungi[7]. Compared to the commercially available hydroxyanthraquinones, most possess an additional methyl substitution in position three, although such a substitution should not be a problem with regard to dyestuffs. However, many anthraquinones derived from fungi have hydroxyl groups located in a β-position, and are not considered valuable to the dye chemist. In addition, many fungi produce not one but a mixture of differently substituted anthraquinones; again, the anthraquinone is considered unsuitable for use as a dye intermediate if a single component is not responsible for at least 70% of the total biochromophore[8]. Therefore, fungi producing an anthraquinone of a single type with only α-substitutions, and in greater than 70% purity, were sought.

Biological production of a dye intermediate

A comprehensive screen of a wide range of fungi reported to produce anthraquinones suitable for subsequent conversion to a dyestuff was carried out. In most cases, the anthraquinone with α-substituted hydroxyls only was a minor component of the anthraquinone mix produced. However, a strain derived from the filamentous fungi *Curvularia lunata* CBS 294.61 was found to produce the anthraquinone cynodontin (Figure 2) in sufficient purity to be converted to a dye. Cynodontin is tinctorially the strongest and most bathochromic of the hydroxyanthraquinones, which makes it a useful dyestuff intermediate.

Initially, only trace amounts of cynodontin were produced by *C. lunata*. After strain selection and manipulation of media and incubation conditions yields were increased, to allow sufficient of the cynodontin to be produced for subsequent conversion to a dyestuff.

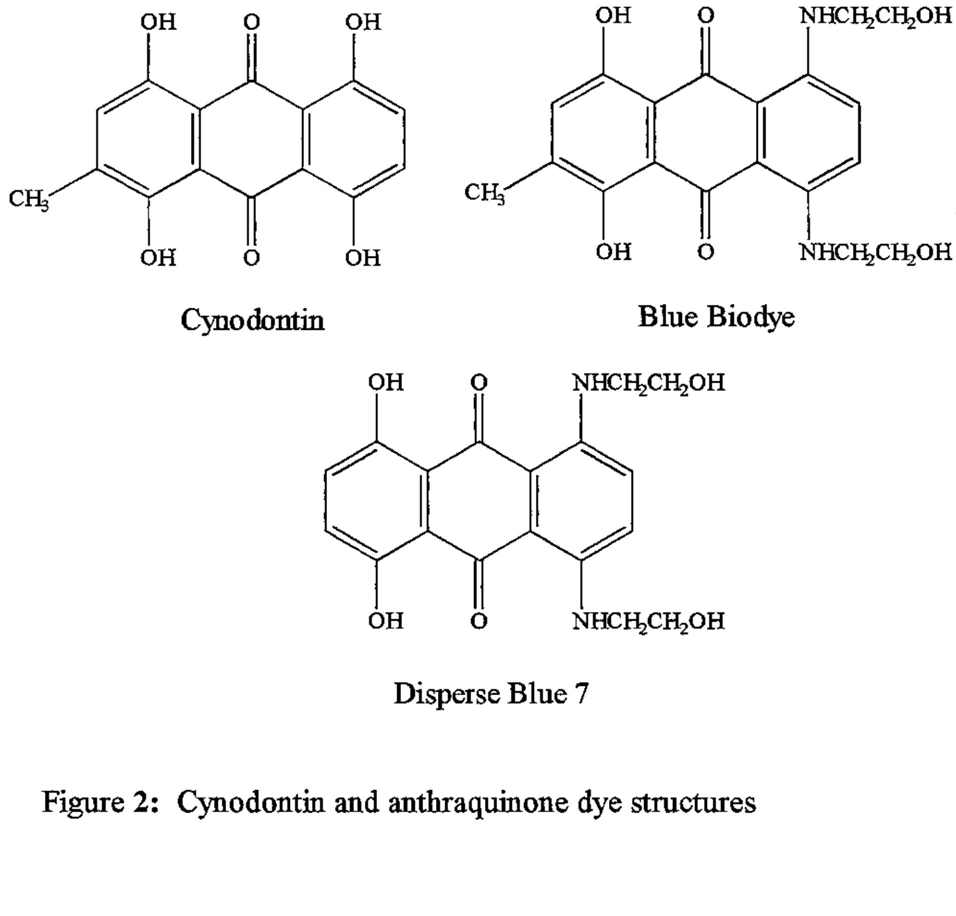

Figure 2: Cynodontin and anthraquinone dye structures

Table 2: Comparative properties of conventional dye and biodye applied to knitted polyamide

Dye	Blue biodye	Disperse Blue 7
Solubility	Good	Good
Dyebath deposition	Some	None
Dyebath precipitation	None	None
Levelness of colour	Good	Good
Light fastness (Xenon)	-6	5-6
Colour fastness		
Hard water		
Change in colour	5	4-5
Staining polyamide	4+	3-4
Viscose	5	5
Wash 3 (60°C)		
Change in colour	2B	1-2G
Staining polyamide	2+	-2
Viscose	4-5	4-5
Hot water		
Change in colour	4G	3G
Staining polyamide	-3	2
Wool	14	3+

Production and properties of a blue biodye

Cynodontin was successfully converted to a blue biodye by condensation with ethanolamine[9]. The biodye had a similar structure to that of Disperse Blue 7, the only difference being in position 3 where the hydrogen of Disperse Blue 7 was replaced by a methyl group (Figure 2).

The fastness properties of the synthetic dye and the biodye, applied to polyamide at one third standard depth of shade, are compared in Table 2. The biodye was found to possess comparable dye properties to the conventional dye, with equivalent or slightly better fastness properties. For example, light fastness of the biodye was slightly better than that of Disperse Blue 7; values of –6 and 5-6 respectively were recorded on the Light Fastness Scale, where 1 represents minimum and 8 maximum fastness. Fastness of the biodye to other test conditions, e.g. fastness to hot water (70°C), were measured on the Geometric Grey Scales. These scales range from 1 to 5 where 1 represents severe shade change or degree of staining, and 5 represents no shade change or degree of staining. Fastness of the biodye and chemically synthesised Disperse Blue 7 were recorded as 4G and 3G respectively where G represents a change to a greener shade in each case. The blue biodye also appeared brighter than its chemically synthesised counterpart, possibly a result of the 3-methyl substituent.

COLOUR REDUCTION IN TEXTILE EFFLUENT

In principle, decolouration of dye containing effluent is achievable using one or a combination of the following methods: adsorption, filtration, precipitation, chemical degradation, photodegradation, and biodegradation. Colour removal at the sewage works is viewed by the water companies as a temporary measure, with dedicated systems in dyehouses being the preferred option. In theory, however, biological treatment gives the ideal solution to colour removal as less sludge is produced in comparison to chemical treatments. Also lower daily running costs are incurred.

The bacteriological degradation of textile dyes has been investigated by a large number of researchers. The decolouration of azo-based dyes has been attributed to the reductive cleavage of the azo bond[10].

$$R_1\text{-N=N-}R_2 + 4e^- + 4H^+ \longrightarrow R_1\text{-}NH_2 + R_2\text{-}NH_2$$

where R_1 and R_2 = aromatic substituents in dye molecule

Under anaerobic conditions, the azo reduction reaction is catalysed by various biological systems, particularly azoreductase enzymes[11]. Alternatively, it is known that many gut organisms produce extracellular flavanoid compounds that reduce azo bonds in food grade dyes.

Biological treatment methods

In principle, biological treatment systems for the removal of colour from textile effluent offer the best solution. However, in practice, such systems are often combined with physico-chemical methods of removal[12, 13]. Conventional aerobic systems fail to remove many dyestuffs and may be subject to mechanical breakdown, expensive capital and running costs, susceptibility to shock loadings, occupation of large areas of land and production of large quantities of sludge. The PACT® system (Zimpro Environmental Inc.) is an example of the combination of a physico-chemical method of colour removal combined with a conventional activated sludge process. Powdered activated carbon is added to the waste stream before treatment, to the recycle sludge or to the aeration tank itself: the point of addition makes little difference to the overall removal of BOD, COD or colour. A carbon dose of 400ppm increased BOD removal from 79% to 96%, COD removal from 56% to 86% and colour removal from 0% to 95% from an undefined effluent stream[14].

A variety of aerobic effluent treatment systems are available. The Deep Shaft process, developed by ICI is a variation of the activated sludge process, but utilises less space as the system is contained within a deep hole below the ground. The hydrostatic pressure at the bottom of the column improves oxygen transfer to a mixture of raw sewage and activated sludge[15]. Biological aerated filters (BAF systems or Biofilters) comprise a submerged packed bed, with fixed biofilm, which is continually aerated[16]. The reactor must be periodically backwashed to remove excess biomass and trapped solids. BAF systems occupy less space than activated sludge processes and treat greater loads of BOD (up to 8kg BOD/m^3 day, compared with 0.6kg BOD/m^3 day for activated sludge and 0.4kg BOD/m^3 day for trickling filters). The biofilm in rotating biological contactors (RBC) is formed on a series of discs that rotate at right angles to an incoming flow of sewage. Excess microbial growth is removed by a combination of predation and mechanical action, in a similar manner to the trickling filter. Reactive dyes, however, are not removed by these aerobic systems, but must be eliminated during prior chemical coagulation and flocculation treatments.

Anaerobic biological treatment processes may degrade azo dyes to the corresponding aromatic amines[12]. Such processes usually occupy less space, treat wastes containing up to 30,000mg of COD per litre, have lower running costs and produce less sludge. However, reduction of sulphur compounds under these conditions produces odour problems, but these problems may be overcome by the use of biofilters and bioscrubbers. Other anaerobic systems are available, including both upflow and downflow anaerobic filter configurations of BAF type systems, and continuous stirred tank reactors. The aromatic amines generated during anaerobic digestion may be subsequently treated using aerobic biological treatment, which is one solution to the problem that the aromatic amines are generally more toxic than the dye itself[12].

In most biological based treatment systems the possibility exists of enriching the microbial population with acclimated or specifically isolated bacteria to aid degradation of a specific dyestuff or dye class. One example would be the use of a *Shewanella sp.* isolated from an industrial effluent stream, that has been shown to degrade a range of reactive dyestuffs including the commercially important dye Remazol Black B. The action of the bacteria was enhanced under anoxic conditions, and reductive degradation of the dye by an extracellular flavin was the proposed mechanism[17].

DYES AND MICROBES; COLOURATION AND DECOLOURATION

The use of microorganisms offers a potential solution to the environmental cost of both the production and use of certain dyes.

Exploiting a microfungus to produce anthraquinone dyestuff intermediates eliminates the need to use strong acids, heavy metal catalysts and the large amounts of energy required to maintain the high temperatures needed for synthetic production. Cynodontin production by *C. lunata* occurs at 28°C and requires only a mineral salts medium. To date, impressive yields of cynodontin have been produced, but these are still not high enough to warrant full scale commercial production. Genetic manipulation probably offers the best prospect of improving yields to a commercial level.

The use of microbial systems is also the ideal solution to colour removal, especially some reactive dyes that are difficult to remove by other techniques. Biological treatment produces less sludge in comparison to chemical treatments, and also incurs lower daily running costs. The prospect of acclimatising bacterial populations from existing treatment processes to particular effluent compositions, or enriching such populations with isolated bacteria that are particularly effective in degrading specific dyes or dye classes is attractive.

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ENVIRONMENTAL CONSEQUENCES OF USING FLAME RETARDANT TEXTILES - A SIMPLE LIFE CYCLE ANALYTICAL MODEL

A. Richard Horrocks, Michael E. Hall and Dawn Roberts

INTRODUCTION

Environmental concerns are such throughout the world that all manufacturing processes, product servicing and disposal histories are currently under close inspection. This is especially the case in developed areas and notably within the EC where environmental legislation is at various stages of implementation.

For instance the UK Environmental Protection Act of 1990 was enforced fully by late 1995 and during this period presented serious implications for the textile and general manufacturing sectors[1]. By the time of its full implementation, the UK regulations now fall within the wider context of EC legislation, which has defined targets with respect to reduction in effluents and waste relating to the textile chemical finishing sectors and especially the textile flame retarding industries.

Simultaneously in 1992, the consequences of UK environmental legislation on the UK textile industry and an attempt to audit the particular problems afforded by finished textiles were reviewed by Cooper [1] and, for flame retardant textiles, by ourselves [2]. This latter paper attempted to consider a "cradle-to-grave" audit and provided a life cycle analytical model, which was tested on flame cellulosic, retarded textiles and inherently flame resistant polyester textiles. Within the EU these represent two competing flame retardant materials for similar end-use applications and yet provide examples of completely differing textile production, service, aftercare and disposal histories. To our knowledge, this study still represents the only published attempt to undertake a full environmental audit life cycle analysis of flame retardant textiles although more focused papers have considered the environmental factors relating to man-made fibre production[3] and flame retardant systems generally [4]. This current paper extends the formerly addressed model [2,5] to include the main flame retardant textiles in use within the US and EU.

COMMONLY USED FLAME RETARDANT FIBRES AND TEXTILES

The majority of flame retarded textiles are non-durably and durably flame retardant finished cottons which find use in temporary and permanent drapes, bed covers, mattress covers, furnishing fabrics and protective clothing where legislative, customer or code of practice demands an ideal balance of flame retardance, textile performance and cost-effectiveness in both domestic and contract sectors [6] . The remaining minority comprises a range of flame retarded or inherently retardant conventional fibres (eg. wool, viscose, polyester, etc.,) and the often-called high performance heat and flame resistant fibres such as the polyaramids and polybenzimidazoles, which have been reviewed recently elsewhere[6,7] .

Table 1 summarises all the above major durable types of flame retardant textile and indicates the origin of the flame retardant character. Those containing halogenated retardants are receiving considerable critical attention because of the general desire to reduce the use of halogens and especially bromine in manufacturing processes and the reported generation of dioxins when aromatic bromine-containing species are burnt[8]. The replacement of decabromodiphenyl oxide as an efficient retardant by aliphatic species like

Table 1: Durable and inherently flame retardant fibres in common use.

Fibre	Flame retardant structural elements	Mode of introduction(i)
Natural:		
COTTON	Organophosphorus and nitrogen-containing monomeric or reactive species eg. Proban CC (Albright and Wilson), Pyrovatex CP (Ciba).	F
	Antimony - organo-halogen systems e.g. Flacavon (Schill and Seilacher), Myflam (Mydrin)	F
WOOL	Zirconium hexafluoride complexes, e.g. Zirpro (IWS); Pyrovatex CP (Ciba).	F
Regenerated:		
VISCOSE	Organophosphorus and nitrogen/sulphur-containing species e.g. Sandoflam 5060 (Lenzing FR Viscose);	A
	polysilicic acid and complexes e.g. Visil AP (Kemira)	A
Synthetic:		
POLYESTER	Organophosphorus species: phosphinic acidic comonomer e.g. Trevira CS, (Hoechst); phosphorus containing additive Fidion FR (Montefibre).	C/A
ACRYLIC (modacrylic)	Halogenated comonomer (35-50% w/w) plus antimony compounds e.g. Velicren (Montefibre); Kanecaron (Kaneka Corp.)	C
POLYPROPYLENE	Halo organic compounds usually as brominated derivatives, e.g. Sandoflam 5072 (Sandoz)	A
Inherent:		
POLYHALOALKENES	Polyvinyl chloride, e.g. Clevyl (Rhone-Poulenc) Polyvinylidene chloride, e.g. Saran (Saran Corp.)	H
POLYARAMIDS	Poly(m-phenylene isophthalamide), e.g. Nomex (du Pont), Conex (Teijin)	Ar
	Poly(p-phenylene terephthalamide), e.g. Kevlar (du Pont), Twaron (Enka)	Ar
POLY(ARAMID-ARIMID)	e.g. Kermel (Rhone-Poulenc)	Ar
POLYBENZIMIDAZOLE	e.g. PBI (Hoechst-Celanese)	Ar
OXIDISED ACRYLIC	e.g. Panox (Universal Carbon Fibres)	C/Ar
NOVOLOID (AMINOPLAST)	e.g. Kynol (Kynol, Japan), Basofil (BASF).	C

(1) Key
- F : finish applied to fabric
- A : additive introduced during fibre production
- C : copolymeric modifications
- H : homopolymer
- Ar : aromatic homo - or copolymer

hexabromocyclododecane has been occurring during the last five years or so. The more comprehensive chemistries of flame retardant finishes in Table 1 may be found in references 6 and 7 and citations therein.

Blends have been omitted from the above and current studies, but in many cases flame retardants are selected with respect to the major fibre component present in the blend. For example, cotton-rich or equivalent/polyester blends may be effectively finished with tetrakis (hydroxy methyl) phosphonium condensates like Proban CC (Albright and Wilson, UK). Blends containing inherently flame retardant fibres, either with other inherently or with non-flame retardant fibres, may be assumed to be additive in terms of their environmental impacts although not always in terms of their burning behaviours.

ENVIRONMENTAL RANKINGS AND INDICES (EI)

In a previous paper[2], the environmental index was expressed as the sum of a series of individual rankings of each major production/process/service life/aftercare/disposal stage on scales of 0 - 5 for increasing environmental damage or impact. For typically durably flame retardant finished cotton and polymer-modified flame retardant polyester, respective values of 34 and 38 out of maximum (damaging) environmental scores of 90 were obtained which covered 18 possibly quantifiable "cradle-to-death" stages. While it was difficult to quantify and hence rank each stage for these two quite common flame retardant textiles, the scores were surprisingly similar in spite of their quite different production and process histories [9].

Extension of this life cycle model to all flame retardant textile fibre variants in Table 1 may be made if stages having unknown environmental consequences are compared with data available for the better quantified properties and behaviour of FR cotton and polyester. This is shown in Table 2 for eleven different generic flame retardant fibre types for which all respective production, process, aftercare and disposal stages are identified and ranked [2]. For instance, hydrophobic fibres in Tables 1 and 2 will show similarly low aftercare energy inputs and waste water outputs to those previously discussed for polyester [2]. Furthermore, it may be assumed that textile finishing processes and flame retardance introduced during polymerisation or fibre production stage(s) will be respectively very similar in general environmental terms since the flame retardant comonomers and additives introduced are similar to those used in flame retardant treatments [6,9]. However, for some fibres use of substituted alkene monomers containing halogens and/or nitrile groups will have possibly serious environmental consequences during production and service life and disposal if they or degradation products are released. Of particular note here are the known toxicological properties of acrylonitrile and vinyl chloride monomers and the release of HCN and HCl respectively during combustion or incineration.

Environmentally acceptable disposal of all synthetic fibres poses problems regarding their non-biodegradability - polyaddition and aromatic fibres provide a particular challenge for potential recycling in that reduction to respective monomers is difficult, if not impossible and unacceptably costly, even if feasible.

Notwithstanding, attempts to enumerate respective environmental indices (EI) have been undertaken and the results are presented in Table 2. Life cycle stages presented have been modified relative to those published previously [2,5]. Attempts have been made to rank the environmental consequences of each stage for each fibre; dashes indicate that the stage is irrelevant for certain fibres. Rankings for the inherently flame retardant fibres, for which relevant quantitative data are rarely available and little non-commercial information exists, have been made based on chemical intuition following careful study of their characteristics - consequently they may have considerable error.

The rankings ignore the fact that recovery and recycling within the textile and fibre industries are generally considered to be quite efficient processes and that a given fibre may be physically recycled several times during its lifetime. This is especially the case for some of the very high value aromatic, high performance and oxidised acrylic fibres where process waste generated during high value product manufacture is recycled. However, such recovered fibres, while being streamed into lower value products, such as nonwoven heat barrier felts, still have a definable process and lifetime environmental history.

CONCLUSIONS

Resulting environmental indices are shown schematically in Figure 1 in descending order from modacrylic (EI = 51%) to novoloid (EI = 32%) fibres. A more full analysis of the separate stages, the assigned rankings and factors affecting them have been reported elsewhere [10]. However, while the error associated with individual rankings for each stage in each fibre life cycle prevents their critical comparison, it is worth noting the following points:-

(i) all fibres have indices within the range 32-51% which suggests that they all are relatively environmentally acceptable based on the semi-quantitative ranking method;

(ii) this range suggests that either the model does not discriminate effectively or that currently available flame retardant fibres do indeed have surprisingly similar environmental impacts;

(iii) the latter inference may indicate that overall acceptability of each fibre history stage and the total process history in terms of commercial and current environmental and safety regulations within the USA and EC will effectively eliminate potentially extremely environmentally hazardous materials; and

(iv) a sensible average ranking value of about 2 per life cycle stage would be a laudable aim for fibre and textile manufacturers to strive to achieve and so improve the overall environmental acceptability of their products - this would give rise to an environmental index of 40%, a value which all except three of the fibres in Table 2 exceed.

Clearly, while the above strategy generates a relatively simple environmental life cycle model, this can be more rigorously tested only if quantifiable environmental impact data exists or is available for all fibres selected.

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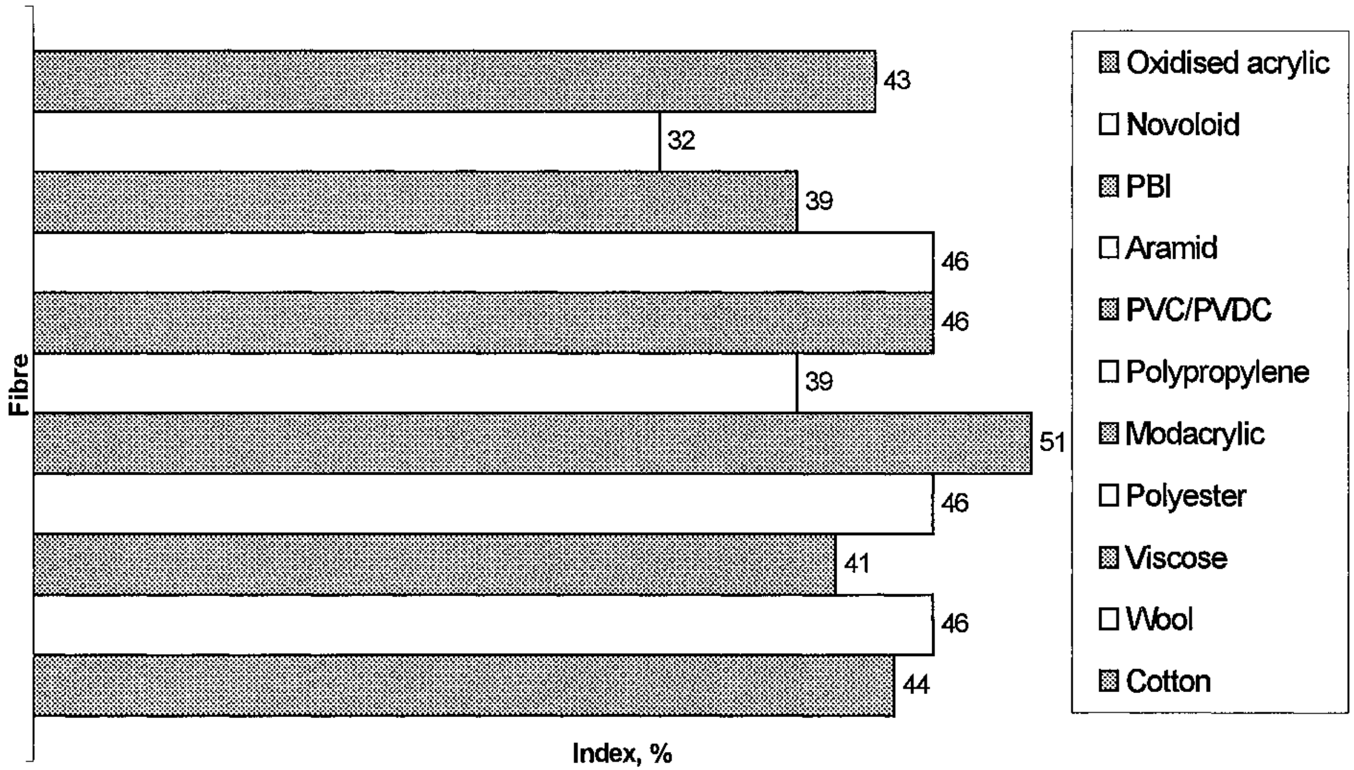
Table 2: Rank-referenced environmental audit of flame retarded textiles in Table 1.

Life Cycle Stages [1]	Cotton	Wool	Viscose	Rankings 0-5[2] Pet	Mod	PP	PVC PVDC	Ar	PBI	Nov	Oxy
FIBRE PRODUCTION:											
Fertiliser, Pesticides	4	4	1	-	-	-	-	-	-	-	-
Energy/total oil	1	1	2	4	5	3	4[3]	4[3]	4[3]	4[3]	5
Waste [4]	1	1	3	1	3	1	3	4	4	4	5
Industrial Pollution	0	3	5	4	4	4	5	4	4	4	4
TEXTILE PROCESSING:											
Yarn/fabric production	3	3	2	2	2	2	2	2	2	2	2
Fabric preparation	3	3	1	1	1	1	1	1	1	1	1
Energy input	2	3	3	3	2	2	2	3	2	2	2
FR PRODUCTION/APPLICATION:											
FR introduction/ finishing (effluent)	3	2	1	1	1	3	3	1	1	-	1
Energy input	2	2	1	1	1	1	-	-	-	-	-
Toxicology	1	1	1	1	1	1	1	1	1	-	1
COLOURATION:											
Energy input	2	2	2	3	1	1	1	2	-	-	-
Effluent	4	4	2	2	-	-	2	-	-	-	
END-USE:											
Combustion: CO/HCN	4	3	4	3	4	3	3	2	1[3]	1	1[3]
Toxicology	3	4	3	4	5	3	2	2	2[3]	1	1[3]
AFTERCARE											
Launderability	4	2	3	2	2	2	2	2	2	1	2
DISPOSAL											
Landfill [5]	0	0	0	5	5	4	5	4	4	4	5
Incineration	1	2	1	2	3	2	3	3	3	2	4
Recyclability [4]	2	1	2	2	4	2	4	4	4	3	5
Total ex 90	40	41	37	41	46	35	41	41	35	29	39
Environmental Index %	44	46	41	46	51	39	46	46	39	32	43

<u>Notes:</u>
(1) - Stages exclude environmental consequences of producing FR species (comonomers, additives, finishes, dyestuffs, detergents).
(2) - Pet = polyester, Mod = modacrylic, PP = polypropylene, PVC = polyvinyl chloride, Ar = polyaramids and arimids, Oxy = oxidised acrylic fibres, Nov = novoloid.
(3) - No results available; estimates based on comparison with other fibres.
(4) - Ease of remelting/dissolution/solvent recovery/hydrolytic decomposition/biodegradability are influential factors here.
(5) - Refers to potential biodegradability.

Figure 1: Environmental Index Values for Flame Retardant Fibres



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THE IMPACT OF ENVIRONMENTAL ISSUES ON TEXTILE DESIGN EDUCATION

Therese Squires

INTRODUCTION

The aim of this paper is to describe and evaluate the impact that environmental issues have had on the curriculum development of the five courses that are offered by the Department of Textiles /Fashion at the Manchester Metropolitan University. The Department is currently one of the largest providers of Textile / Fashion Education in the UK. We offer BA Hons degree courses in Textiles, Fashion, Embroidery, Fashion Design with Technology (run jointly with Hollings Faculty), Post graduate Diploma and MA in Textiles and beyond to
M Phil and PhD

Although these courses differ with regard to their area of specialism the BA Hons do share some common elements at levels one and two and the MA students join in various activities relevant to their individual program of study.

The present methods of curriculum delivery will be described then a specific project that includes an awareness of sustainable issues as part of the assessment criteria will be outlined. The support mechanisms for individual students desire to study the issues in depth as part of their practical or theoretical studies is also explained. The effectiveness of the course delivery will finally be evaluated.

UNDERGRADUATE PROGRAMMES

Course Aims

The general aim of the BA Hon courses is to provide a program of studies that enable the student to fully develop their intellectual and creative potential, to acquire knowledge and skills relating to their chosen subject in a progressive manner. We encourage the students to acquire an analytical approach to problems, applying critical judgement and learning to conceive, realise, communicate and evaluate solutions in a clear and logical way. The students are introduced to the wider horizons of art and design. Their natural curiosity and talent for observation are encouraged, while at the same time their aesthetic vision is broadened.

Curriculum Development

As the Department of Textiles and Fashion moves towards the next century staff are aware that funding will become even tighter and student numbers will increase. Student's career aspirations have changed, as have the needs of prospective graduate employers. In response to these external factors we have rapidly developed alternative methods of course delivery that we believe are more relevant, effective and efficient.

Specific staff research and development programs have been undertaken by staff to update their professional practice and add to the knowledge base of the department.

The course teams believe that the textile and fashion designers have an important role to play in the evolution of the industry and the future of the environment and the designer must be aware at all stages of the design process the needs and repercussions of building in environmental friendliness to the end products, be they intended for commercial reproduction or 'one off' objects.

As part of this program of research the impact of the fashion and textile industry on the environment was highlighted as necessary for our future curriculum developments. This was undertaken by several members of staff and has resulted in the inclusion of lectures and projects that aim to stimulate an awareness of sustainable issues in a relevant and interesting way within our graduate and post-graduate student body.

A project examining the impact of Textiles and Clothing Production on the environment has been undertaken by Jo Heeley and this has involved the department and researcher in collaboration with outside bodies, leading to the establishment of the Textile Environmental Network (TEN). This group evolved out of the desire for a better provision and exchange of information, knowledge and ideas relating to the environmental performance of textiles and their production. Students have the opportunity to become involved in this network and the TEN resource guide is available for students.

Student experience at pre-degree level

Students are accepted onto our first-degree courses from varied routes. Direct entry from school, BTEC National Diploma, GNVQ, Foundation in Art and Design or HND. Their experiences are as varied as their courses.

A student survey of the three levels of the BA Hons Textiles course was undertaken to establish if any of their pre degree curricula had included projects or lecturers that dealt with sustainable issues directly relevant to textiles and fashion.

At first a questionnaire was devised that was generally distributed around the studio. The best method of obtaining information was to gather the each level together and discuss their prior experiences and awareness of the ecology issues. This also had the advantage of allowing the students to voice their opinions as to how such issues effected them and their creative work. 48 level one textile students and 32 level one fashion students together were gathered and it was found that 80 % of the students had previously undertaken some form of recycling project at pre-degree level. This percentage increased when the same question was asked of the 42 level two textile students and of the 39 level three textile students. The students believed that the projects were set more as a response to economic constraints and lack of sufficient finance for class materials rather than as a direct response to the environmental issues. The projects had not been reinforced by lectures / seminars or discussions about environmental or sustainable issues.

Half the students of all levels questioned practised some form of recycling at home or at college, this included taking empties to the bottle bank, saving newspapers, donating clothes to charity and putting drink cans and paper offcuts in the appropriate bins at college. The remaining students felt that the issues did not effect them or their actions would not effect the environment.

Royal Society of Arts Student Design Awards 1997/98

The level three Textile students are expected to enter the Royal Society of Arts Student Design Awards during the first semester of their final year. One of the general criteria for all the questions this year included 'an awareness of sustainable issues whenever appropriate relating to choice of materials, packaging etc.'. In order to make the students aware of the issues involved in answering the brief a lecture entitled "The use of Textiles and the

Environment" was given. 33 of the 39 students attended the lecture. The remainder obtained the lecture notes from their colleagues.

A synopsis of 'The use of Textiles in the Environment' included:

- Textile and clothing as a major employer in the UK
- The link between the processes including fibre cultivation and manufacture, manufacture of fibre colouration, colouration of fibre and cloth, cloth manufacture, finishing of the cloth, manufacture of the end product, energy consumption in production, distribution and packaging, use of solvents and detergents in the cleaning, the waste disposal of the products.
- Dying, covering natural dyestuffs, land use, chemical use, waste matter, synthetic dyestuffs, current legislation and control.
- Wool, including production, properties, advantages and disadvantages.
- Cotton, including production, properties, use of pesticides, water consumption, need for tighter control worldwide, experiments with organically grown cotton and the disadvantages.
- Linen including production, advantages and disadvantages, bleaching.
- Silk, production and properties.
- Synthetics covering fossil fuels, regenerated fibres, history, properties, manufacturing processes and current legislation.
- Finishing covering process, chemical use and current legislation.
- Recycling and current practice, TEN resource guide.
- Conclusion. We do not have the answers!

This lecture does not investigate the issues in depth but is designed to raise the awareness of the subject and allow the student the opportunity for further investigation and study. This lecture was delivered to the constructed textile students (about 17 students) during the previous academic year, level two, as part of their technical lecture program but not followed up by a specific project.

During the course of the RSA project the group of students were required to take into account sustainable issues when designing and specifying their fabric. Some students achieved this with greater success than others. Most submissions for the RSA demonstrated that the students had taken the issues on board and had thought creatively around the problems.

The choice of yarns for the weavers and knitters was governed by availability and proved to be problematic. We have difficulty in obtaining small quantities of yarn from the manufacturers also we are unable to dye and handle many of the synthetic yarns by hand and therefore the choice was mainly limited to natural fibres. The ranges of recycled yarns currently available are limited and not always appropriate to the brief. The choice of yarn, base cloth and production method is always part of the design process but students had become more aware of the repercussions of their choices and decisions.

The judging of the Student Design Awards is currently taking place. It is naturally difficult at this time to obtain feedback from the RSA juries about the national response to the inclusion of 'an awareness of sustainable issues whenever appropriate regarding materials packaging etc ' as one of the general criteria for judging the entries.

It is difficult to successfully visually demonstrate on a series of A2 boards that the entry has fulfilled this part of the required criteria. It is more likely that the student thinking is only apparent in the reports and sketchbooks that accompany the submission.

The verbal feedback from this group of students was that they had taken on board the issues presented to them in the form of a lecture and that their own personal design development had been influenced by the inclusion of an awareness of sustainable issues as one of the criteria for the submission.

Dissertation

The three BA Hons courses in the department of Textiles/Fashion all require the submission of a dissertation of between 8 and 10 thousand words that equates to 20% of the final mark of the BA Hons degree. The research element of the dissertation begins during the second semester at level two and the final writing up is completed by January of the final year

A first class dissertation will include a comprehensive and critical review of relevant primary and secondary sources. The sources are properly investigated, rigorously questioned and incorporated into a structured dissertation. The dissertations are both held in the library and the department for reference and are available to students and staff.

Over the last six years a number of students have chosen to research and write about varied ecological issues that have arisen as a result of the students personal interest or from a raised awareness of ecological issues triggered by attending related lecturers that are now part of the contextual study or technical lecture programme.

Dissertation titles since 1992 have included the following titles:

1992	Can Fashion be Green?	Jo Heeley
1994	Can the Fashion Industry ever be Green?	Liz Pulfrey
	Is Natural Dyeing Commercially Viable?	Sharon Billingham
1995	Education and Environmentalism. If designers of the future need to be able to deal with environmental issues, is our state education system instilling sufficient awareness?	Claire Watson.
1996	Green Fashion. Was it a passing fad or has it has a long-term effect?	Rachel Brown
	Artists Who Use Recycled Material	Linsey Rowley
	Is Design Worth the Paper it is Written on?	Lydia Roach
	Is Recycling in Fashion Just a Passing Fad?	Louise Sweeney
	Packaging and Consumerism. What are the Environmental Issues?	K. Deakon
1997	Natural v Synthetic Dying	Anna Watson

The dissertations are supervised by a team of supervisors made up from all staff from Textiles/Fashion and some staff from Art History. The dissertation is marked by the supervisor and then second marked by another member of the supervisory team. This allows a large spread of individuals to both supervise and mark. Consequently this also has the effect of raising the awareness of sustainable and ecological issues among the supervisory team.

The students conduct dissertation seminars during the second semester of their second year in part preparation for the writing up of their dissertation research. A group of about eight fellow students and a member of staff attend the seminars. The students are required to present their research and lead a discussion with their colleagues. Whatever the chosen topic is, there have been some very interesting discussions that have continued well beyond the seminar. A student choosing an ecological or sustainable issue is almost guaranteed to find that their colleagues have strong views on the subject and a lively and hopefully constructive debate follows that has the added bonus of reinforcing student awareness of the issues under discussion.

POST GRADUATE RESEARCH

In 1992 Jo Heeley, then a final year student on the BA Hons Textile course wrote a first class dissertation on the relationship between the fashion industry and the environment. The importance of furthering such research was recognised by the Department and a Research Degree for MPhil / PhD was registered. This has been successfully completed by Jo Heeley, (December 1997). A successful bid, E-Co Challenge, prepared in collaboration with the Department of Trade and Industry is now underway and Jo Heeley will remain within the University to continue with research at postdoctoral level. The impact of such postdoctoral research to the Department as a whole is expected to be significant.
See poster session entitled 'Current Product Development Within Design for Environment in the UK Textile and Clothing Industry'.

Major Project

During the final year the students from all three BA Hons courses engage in a concentrated period of negotiated study, the 'Major Project'. Students, with help and advice from staff, develop their own personal projects that allow them the opportunity to study in depth their area of specialism. Individuals with a particular interest in the environment have chosen to base or include ecological or sustainable issues into their program of study. Over the years there have been some very interesting and exciting major projects that have attracted considerable attention at degree show exhibitions and at national exhibitions such as New Designers.

Liliane Taylor who graduated in 1994 worked on a project using recycled embroidery and details of cuffs, collars, etc. The recycled embroidery was traditional embroidery originating from mats, tablecloths and chair backs. From these materials a collection of fashion fabrics were created, some of which were made up into men's shirts and jackets. Josie Hall, who graduated the following year, based her final year project on recycled clothing worn by the male members of her family. The final collection reflected the different characters of the original wearers of the garments. Jose went on to complete a Masters Degree at Manchester in 1996. Cheryl Sinclair developed a series of layered and stacked installations using obsolete telephone directories. These were dyed at the edges and then manipulated to show the repetitive layering. After graduating Sheryl completed an MA in Environmental Arts at Manchester where she continued to develop installations using recycled materials

This current academic year Claire Norcross is working on three-dimensional interior structures that use recycled scrap materials. At present PVC tubing and nylon bristles are being utilised.

CONCLUSIONS

Over the last ten years it has become apparent that environmental concerns and consequences are impacting on the role of the artist and designer. Much of the environmental impact of a product is decided at the design stage when specifying materials and process. Staff research and development programs that examine the impact of environmental issues have been undertaken to broaden the knowledge base of the department.

Sustainable issues are now an integral part of the curriculum and it can be seen from the case study of the RSA Student Design Brief that a group of students can appreciate the relationship between the design, production, distribution, consumption and disposal of

products and utilise this knowledge in the design and development of their work. It is seen as important to follow up lectures / seminars with practical project work.
Individual students are encouraged and supported to fully develop their personal research both in theory and practice and it is apparent that some students strive to incorporate environmental research ideas and findings in to their work.

The E-Co project is seen as a significant factor in the continuing involvement of the Manchester Metropolitan University in the debate and development of the teaching of environmentally aware design and research ideas.

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