Section 1: Waste Minimisation

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WASTE MINIMISATION CHALLENGES IN THE UK TEXTILE INDUSTRY

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INTRODUCTION

Waste minimisation is the term used to describe the process of systematically reducing waste at source. But what is waste? - many consider it to be discarded materials but it includes wasted money, time, loss of materials (to air and drain), excessive use of energy and water, and product give-away through overfilling of packages and containers. Waste minimisation will save money - typically up to 1% of business turnover either as extra profit or as reduced operating costs.

A structured approach to waste minimisation will give a company more control over its disposal costs. It will be cheaper and easier for companies to comply with environmental legislation and it will improve a company's reputation with customers who seek assurance that their suppliers are operating on a sound environmental basis.

Every process in a company produces waste and is therefore a potential target for waste minimisation and increased profits. So how can the textiles industry, historically thrifty in sold waste, meet the opportunities and challenges of waste minimisation? Companies can take on waste minimisation and efficiency in environmental management can benefit the bottom line and so the environment; thus the need to meet legislation, is not always a cost. The Environmental Technology Best Programme can assist companies in achieving waste minimisation and hence improves overall performance. The Environmental Technology Best Practice Programme is a UK Government initiative which promotes the use of better environmental practices that reduce business costs for UK industry and commerce. The ETBPP's key objectives are to help companies become more efficient through waste management, thus reducing costs and assisting competitiveness.

The ETBPP is funded jointly by the UK Government Departments of Trade and Industry (DTI0 and Environment and Transport and the Regions (DETR) and managed by ETSU and the UK's National Environmental Centre, NETCEN. The Programme covers eleven industrial sectors and two generic topics, waste minimisation and clean technology.

The clothing, textile and footwear sector is important in the UK economy representing just fewer than 7% of total customer expenditure - at £23 billion per year, it is a very significant market sector. The textile-manufacturing sector is also a significant employer, particularly in certain regions. However, the last few years have seen flat consumer consumption. It also appears that no more than modest growth in consumption can be predicted in the short to medium term future. While the industry is competitive and still undergoing restructuring, besides effective management both of the manufacturing process and the supply chain to remain competitive in world markets, the sector needs cost effective means to identify best practice techniques and technologies to further aid its competitiveness.

The UK clothing market is characterised by the dominance of the seven major chain store groups, which account for almost half the UK clothing sales. These include Marks and Spencer, the Burton group, Bhs, Next and Littlewoods. The fastest growing retailers include smaller chains such as Oasis and New Look, while the most profitable are Burberry, River Island and Monsoon.

Imports of textiles and clothing into the UK remain high, primarily from low labour cost countries. Three quarters of UK imports came from outside the European Union in 1995. Comparatively exports represent a fraction of the value of imports resulting in a trade deficit of £2,339 million in 1995. UK textile production decreased by 2.8% in 1995, but this was a modest decrease compared to many European States. A slight improvement in production is forecast for 1997 and in the clothing sub-sector production has increased by 2.4%: the increase is particularly pronounced for knitted products.

Over the past few years there has been a perceived shift towards smaller order sizes as retailers are demanding shorter runs of higher numbers of fashion lines and as they sourced larger amounts of their basic lines from cheaper overseas suppliers. Additionally companies taking the route into higher value markets are expected to have to adapt to smaller order sizes from more exclusive retail customers. Paralleling the shift towards smaller orders has been the continued clear trend toward shorter lead times between manufacture of a garment for example and its appearance in the retail store. The sectors most affected by shortening lead times are the mid market retail chains, the corporate clothing market, the quality independent retailers and the discount and wholesale retail markets.

Underlying these developments is the changing relationship suppliers have with their retail customers, and the increasing demands the major retailers are placing on their domestic suppliers. For example the old two-season year is disappearing with products now having shorter life cycles. Many retailers expect to sell a series of stock ranges within any given six month selling period. As well as this there is an increased frequency of delivery now demanded by retailers? 87% of variety chains now replenish their stock often on a daily or weekly basis. Bhs's Director of Operations recently invited UK manufacturers to deliver products, which have a different edge from those of their foreign counterparts. In order to compete with overseas competition the opportunities for growth lie with manufacturers who can "add value to their products, get those products faster to the retailer at a consistent quality and when the retailer wants it". Bhs do not consider price to be the only criteria when choosing their suppliers. "In a climate where sales are unpredictable, styles have shorter life cycles and many retailers take big gambles and may be faced with having to mark down stock. Therefore the importance of sourcing suppliers who can deal with short lead times needs to be exploited," states this same spokesperson.

ENVIRONMENTAL PERSPECTIVES AND PRESSURES: ETBPP

Environmental issues are creeping into the supply chain as consumers and retailers are becoming more environmentally aware. Those particularly involved in textile automotive products are becoming increasingly aware of customer requirements to achieve ISO14001 the international environmental management system standard.

Companies are increasingly aware of the benefits, not just in terms of production efficiency, in taking a proactive stance on the environment. Key points in relation to environmental management are:

- good house keeping
- building customer confidence
- strategic considerations

Under the ETBPP issues are mainly of good housekeeping - e.g. minimising energy consumption, raw material use and other waste. Environmental Management Systems (EMS) - which provide comprehensive check lists of action for companies to guard against environmental risks - are part of good housekeeping and effective management.

In many cases, large companies can effectively manage their own environmental affairs but small and medium size enterprises (SMEs) often do not have the resources to examine environmental issues in detail. The ETBPP particularly targets SMEs and can provide assistance. The programme also tries and keeps companies up to date on cleaner technologies and so helps them look to the future.

The ETBPP is focused on the future and to the benefit of UK Plc with aims, which are to:

- save UK textile industry £15m per annum.
- increase the international competitiveness of the UK textile industry.
- promote waste minimisation and cleaner technology.

The role is therefore to identify and promote cost savings to all areas of the textile industry.

CASE STUDIES

The Programme works by highlighting case studies, which will benefit the industry; Table 1 below lists a few recent examples.

Packaging is a key area, particularly with the packaging directive coming into force. Although only companies using in excess of 50 tonnes of packaging will come directly under the regulations, there is on going discussion about how to encourage other companies to minimise their packaging. A case study (GC89) with a company in Northern Ireland illustrates that savings of £45,000/year can be made through the elimination re-use and recycling of various elements of packaging. The payback on the capital equipment involved was about a year. Added to this may be increased landfill disposal costs as the landfill tax is imposed and available holes become scarcer.

Traditionally the textile industry has been quite thorough in minimising its solid waste. However, in wet processing water has been cheap and plentiful - now it appears to be neither. Discharge costs are rising and the regulations regarding that discharge have tightened whether it is for pesticides, colour or BOD/COD.

In assessing water use, the start must be to assess outputs and inputs. One Leicestershire dyer's effluent cost was around £50,000 pa. However, under an audit as part of the Leicestershire waste minimisation initiative the true cost of waste was found to be over £150,000. Although not all the waste can be eliminated the audit helped to focus the company's attention on priority areas and they went on to reduce water and effluent costs by 19%.

Simple measures can include the installation of flow meters. Installation of such devices saved one small dyer over £2,000/year as it was discovered one machine was set to use more water than another does. Other simple systems can involve the use of the last wash water into earlier wash stages. This results in both energy and water savings as the water is already pre-treated. A Cheshire based company illustrated water and energy savings in the order of £30,000 by piping bleach wash water back to the scour wash bath. Energy savings can also be obtained through heat recovery from, for example, effluent.

Table 1: Examples of recent ETBPP Case Studies

GC63	**Latex Recycling Achieves Substantial Savings For Little Cost** *Case study demonstrating the economic and environmental benefits of using a latex recovery system at Ulster carpet Mills.*
NC139	**New Technology Reaps Cost and Product Benefits** *Case study demonstrating the economic and environmental benefits to a textile dyer of investing in cleaner technology*
FP70	**Optimised Process Reduces Formaldehyde Emissions** *A future practice report study aimed at reducing the formaldehyde emissions released during the application of a flame retardant finish to fabrics for cotton textile finishing.*
GC110	**Water and Cost Savings From Improved Process Control** *Reduced water consumption, for a textile company, of over 37,000m3/year, with little or no cost leading to savings of over £32,000*
GC89	**Reduced Packaging Brings Significant Savings** *Packaging waste minimisation programme saves worsted spinning company £47,000 in under 8 months*
GC16	**Sites Set on Cost Savings** *Demonstrates the financial and environmental benefits of a corporate approach to waste minimisation.*
GC18	**Minimise Waste - Improve the Bottom Line** *Demonstrates the success that can be achieved by involving financial managers/directors in company waste minimisation initiatives, and by networking with other local companies to share experiences.*
GC20	**Environmental Review Helps Raise Profits** *Demonstrates the cost savings and other benefits that a small company can achieve through an in house environmental review.*
GC49	**Environmental Management System Improves Performance** *Demonstrates the economic and environmental benefits of implementing an environmental management system at a medium sized manufacturing company.*
GC59	**Environmental Improvements Reduce Costs** *Demonstrates how incorporating environmental issues into existing management systems can result in cost savings and environmental benefits.*

Note:To order any of these case studies or other literature please call the free environmental Helpline on 0800 585794.

To improve efficiency companies are developing optimised dyeing processes; modern printing machines use less water and dye. The future may also bring more formaldehyde free finishing and water based coatings to minimise solvent use and VOC emissions.

Colour removal is another issue occupying the East Midlands in particular. Tied to this is the potential for treating on site and recycling the water resulting in significant cost savings. ETSU are trying to evaluate the various methods proposed in order to assess those which are most effective and worth promoting to the industry. Several methods have been proposed and one or two are now running at particular dyers and finishers resulting in significant cost savings through recycling of water, reduction in chemical use and energy savings. However, initial undertakings such as heat recovery from contaminated effluent can result in significant savings.

Waste minimisation clubs can also assist companies in reducing their waste. The benefits of clubs, whether they be exclusively for textile companies or mixed as in the Leicestershire waste minimisation initiative, are that they allow a good exchange of ideas with each company able to learn and the implement various methods of waste reduction. Similar to these Leicestershire firms mentioned earlier and the saving there, in the Aire and Calder river scheme, the involvement of Milliken Industrials led to substantial savings for the company. An example was a reduction in the waste produced from cutting carpet tiles. The measure to reduce the waste cost £2,000 per year the savings were worth £20,500 per year.

The benefits of working together are that each company may have one idea but discussing issues with others sparks off other ideas leading to greater cost savings. Recently a knitting plant was discovered using wool rags, which could be sold for some profit, to mop up oil dripping from knitting machines. A visitor suggested drip trays, which calculated out at a cost saving of £2,000 per year. Also with future tightening of legislation, the benefits of collaboration and its possible effect on competition worries UK companies, which consequently will not talk to each other - the real threat is from overseas not the UK. As yet there is no real collaboration on technical issues.

ROLE OF DESIGN

Those stages at the start of the fabric process are equally important and ETSU is currently undertaking a study to examine ways whereby designers can be made more aware of the impact of their designs on the environment. The designers are often seen as the weak link in the manufacturing chain. The study initially involved a questionnaire survey of designers. Early results indicate there is a gap between what is actually being done and what could be done to improve the environmental performance of the textile industry. Factors, which appeared to distance the implementation of environmental measures specified by a designer, include the following.

Barriers

These comprise:

- time pressures, overburdened with routine work to consider environmental factors;
- poor communication between functions (environmental personnel, manufacturing, design, marketing and production);
- lack of appropriate information/specialist knowledge to consider environmental concerns during the design process; and

- lack of control over materials and processes to be used.

Drivers

The drivers, which may be identified, are:

- cost savings associated with cleaner designs.

From these studies a number of conclusions were drawn of which in the main, lack of control and lack of communication were of prime importance. Some companies, however, were looking at the supply chain and the implications for design when taking into account environmental factors. Finally education during training is important in helping designers appreciate the impact of their designs on the environment.

ASSISTANCE FOR INDUSTRY: GOOD PRACTICE GUIDES

Tables 2 and 3 below list the currently available "Good Practice Guides" which relate to the UK textile industry.

On the dry textile processing side ETSU is producing a series of Good Practice Guides for the worsted, woollen, cotton and garment manufacturing sectors on how to minimise waste. The Guides bring together those waste minimisation and management ideas that are relevant to the management of solid waste. The Guides provide practical help and cite real case studies and the Guides quote both low cost and more high tech answers. Simple measures are often the place to start and can often result in significant savings. For example, one weaver in West Yorkshire used to use 30cm length of finished cloth per piece on which to mark the order number etc. The company realised that at £80 per metre, they were throwing away £24 per piece or around 0.5% wastage. This "mark up" has now been reduced to a maximum of 10cm; reducing waste to less than 0.2%.

To run the programme effectively, ETSU and ETBPP have sought to understand some of the key issues particularly for SMEs and the environment and to this end have organised and participated in a number of seminars and events across the UK. Table 4 lists the events held since 1996 until the early part of 1998. Issues raised include:

- the increasing costs of production particularly raw materials and in many cases water and effluent charges;
- increasing competition - more retailers are sourcing overseas; and
- buyers are becoming more demanding as the consumer becomes more unpredictable -quick response and smaller orders have become the norm. However, the buyer can assist the industry by working with the manufacturing sector to turn environmental friendliness into a positive marketing tool.

The environment is here to stay and industry should include it as part of its total business challenge. Problems remain but these may be summarised as below:

- legislation on the environment will not decrease and recently a Bradford Mill was fined £4,000 over the release of a red list substance. However, efficient environmental management can minimise the risk of discharge - if you scan the prosecution list fines are often due to operator error (perhaps through lack of education) or poor management of drainage systems;

- it is expensive to keep up with new technology and capital is not always easily obtained for investment in pollution control; and

the industry is still hierarchical in structure and management, therefore partner ships with suppliers or retailers are difficult to establish. The concept of teaming across functions doesn't come naturally to the textile industry. UK manufacturers need to start driving the agenda for benefits of UK supply by initiating partnerships rather than reacting to retailers.

Table 2: Textile waste minimisation and management guides

Ref	TEXTILES PUBLICATIONS
	Sector Specific Water Waste Minimisation Guides
GG62	**Water and Chemical Use in the Textile Dyeing and Finishing Industry** *This guide shows companies how to reduce their water and effluent costs, often by as much as 20% or more. Through implementing no-cost and low cost changes. Overall cost savings can be further doubled or trebled when associated savings in raw materials is taken into account.*
	Series of Four Sector Specific Solid Waste Minimisation Guides:
	<u>**Reducing Costs through Waste Management:**</u> *Comprehensive guides giving step by step instructions on how textile companies can achieve often significant reductions in operating costs. Contains simple low cost (or no cost) measures to reduce waste.*
GG42 *(+ ET80)*	**Waste Management in the Worsteds and Knitwear Sectors**
GG79 *(+ ET80)*	**Waste Management in the Woollen Sector**
GG84 *(+ ET80)*	**Waste Management in the Cotton and Man-made Fibre Sector**
GG86 *(+ ET80)*	**Waste Management in the Garment and Household Textiles Sector**
	Benchmarking Information
EG98	**Environmental Performance Guide for the Dyeing and Finishing Industry** *This guide provides a benchmark for assessing specific water consumption compared to others in the industry. The guide is divided into four sub-sectors: woven cloth, fibre and yarn, knitted cloth and garments and will provide the impetus to implement a water minimisation action plan. The guide should be used in conjunction with GG62.*

Table 3: Guides relating to specific minimising technologies and promoting cost savings

	GENERIC GUIDES USEFUL FOR THE TEXTILES SECTOR
GG37	**Cost-effective Separation Technologies for Minimising Wastes and Effluents** *Using Separation technologies as part of a production process can prove more cost effective than using a larger effluent treatment plant. It usually requires less energy, is less capital intensive in terms of plant and can allow the recovery and re-use of individual substances. This guide lists potential suitable technologies, giving detailed information on each.*
GG54	**Cost-effective Membrane Technologies For Minimising Wastes and Effluents** *This guide explains the basic principles and appropriate applications of membrane technology.*
GG67	**Cost-effective Water Saving Devices and Practices** *This guide describes a range of cost-effective water saving devices and practices - some with a payback of only a few days. It highlights the typical water savings that can be achieved for industrial and commercial applications and hoe to identify the most appropriate devices and practices for specific equipment, processes or sites.*
GG71	**Cost-Effective Reduction of Fugitive Solvent Emissions** *This guide indicates the many sources of fugitive emissions of organic solvents from pipeline components and stresses the benefits of reducing such emissions and discusses the different techniques for controlling them.* **For more solvent publications, call the environmental Helpline and ask for the VOC's publication list.**
GG82	**Investing to Increase Profits and Reduce Wastes** *This guide introduces the techniques for identifying the most cost-effective and environmentally friendly solution through an appraisal of the true cost implications of alternatives to current practice.*
	Generic Waste Minimisation Guides
GS25	**Saving Money Through Waste Minimisation: Getting Started**
ET80	**Waste Minimisation: Elements For Success** *To be used in conjunction with Textile Good Practice Guides - Provides general waste minimisation advice including tips and waste minimisation planning and implementation.*
GG38	**Cutting Costs by Reducing Waste - A Self Help Guide** *This guide contains practical advice to help a company develop their own waste reduction programme.*
	Series of three Generic Waste Minimisation Guides:
GG25	**Saving Money Though Waste Minimisation: Raw Material Use**
GG26	**Saving Money Though Waste Minimisation: Reducing Water Use**
GG27	**Saving Money Though Waste Minimisation: Teams and Champions**

ET30	**Finding Hidden Profit 200 Tips for Reducing Waste**
Environmental Management Systems Guide: *(Textiles EMS Guide due 1998)*	
GG43	**Environmental Management Systems in Foundries** *This document provides useful and down to earth guidance for those seeking to inform themselves on BS7750, EMAS and ISO 14001 and what implementation involves. Although focused on the foundry industry, its contents are relevant to any company considering the implementation of formal EMS.*

It is an increasingly tough business environment but the introduction of efficient management and training to take a company forward and face the competition can have benefits through;

- quality
- design
- innovation
- quick response

The ETBPP hopes to benefit the industry through increased efficiency, reduced costs and an awareness of environmental issues and how a pro-active approach may benefit a company especially as environmental factors impose upon the supply chain.

This paper should have illustrated that despite the mass of environmental legislation applicable to the textile industry there are ways of monitoring environmental impact and through efficient management of those resources making significant cost savings. We shall be producing a guide on environmental management for the textile industry. The main purpose of this Guide will not be just to demonstrate how accreditation may be met but to illustrate how environmental management can add to the overall efficiency of a company.

The ETBPP will, through its work, identify new practicable technologies, and identify wherever possible low cost solutions. The benefits of the ETBPP is that it is independent, free and has internal expertise and can obtain information of relevance from other sectors – its main aim is to help industry to address the environment positively. The list presented in Table 4 of recent events undertaken for and with UK industry since 1996, is evidence of the commitment of ETSU and the ETBPP to the UK textile industry.

Table 4: ETBPP participation in textile events in the UK from 1996 to the present time

Organisation	Date & title of Event
London College of Fashion	**13/1/96** The Cut and the Cloth
Manchester Metropolitan University	**29/03/96** Textiles, design and Environment Workshop
Association of Suppliers to the British Clothing Industry	**7/11/96** Annual General Meeting
Textiles Environmental Network	**12/11/96** Material world II conference
Local Action Textiles & Clothing	**25-27/11/96** Textiles & Clothing World-wide - Partnerships, Networks and Collaboration into the Millennium
Hamilton Associates	**12/03/97** Strategy and Management in Textiles and Apparel
Textile Institute	**13/03/97** Textiles Energy and Waste Seminar
EEBPP	**19/03/97** Putting Energy in the Supply Chain
Ayrshire Textiles Group	**30/05/97** Ayrshire Textiles Waste Minimisation Club
Hamilton Associates	**11/6/97** Strategy and Management in Textiles and Apparel
Hamilton Associates	**03/07/97** Strategy and Management in Textiles and Apparel
Nottinghamshire International Clothing Centre	**9/9/97** Reducing waste to Improve the Bottom Line
Textile Finishers Association/CBWT	**2/10/97** Energy and Water Conservation Seminar
Ayrshire Textiles Group	**8/10/97** Ayrshire Textiles Waste Minimisation Club
Business Solutions	**9/10/97** Efficiency in Production
Local Action Textiles & Clothing	**6 - 7/11/97** Textiles and Clothing in the Operating Environment
Nottinghamshire International Clothing centre	**20/11/97** Reducing Waste to Improve the Bottom Line
Scottish Textiles Technology Centre	**21/11/97** Textiles 2000
Textiles Environmental Network	**25/11/97** Teamworking conference
Finishers Environmental Forum	**3/12/97** Use Less and Earn More Taking waste Minimisation Techniques a step further
Ayrshire Textiles Group	**11/12/97** Ayrshire Textiles Waste Minimisation Club
Nottinghamshire International Clothing centre	**25/02/98** Reducing Waste to Improve the Bottom Line
Bolton Institute	**7&8/4/98** Eco Textiles 1998
Lancashire Textiles Manufacturers Association	**9/6/98** LTMA General Meeting
Pendle Business Centre	**16 & 17/6/98** Putting Waste to Work
Programme Events	
EEBPP	**10/12/96 , 11/12/96, 21/1/97, 23/1/97** Increase Efficiency Increase Potential
EEBPP	**21/10/97, 22/10/97** Practice What we Preach!

THE ENVIRONMENT AND THE LAW

Victoria Joy

INTRODUCTION

The textile industry, some sectors of which have significant environmental impacts, is affected more than most by changes to environmental law. This paper will briefly describe the legislative framework, which covers the industry at present before focusing on forthcoming changes. The new contaminated land liability regime is covered in some detail, since it has the potential to affect any business which has ever contaminated land, or which owns or occupies a site which has been contaminated by others.

Environmental control regimes

Air pollution control (APC) & Integrated pollution control (IPC)

The Air Pollution Control (APC) and Integrated Pollution Control (IPC) regimes were introduced by the Environmental Protection Act 1990 (EPA). Various industrial processes are prescribed by regulations under the EPA, the Environmental Protection (Prescribed Processes and Substances) Regulations 1991, and require an authorisation to be carried out. The more technically complex or polluting processes are subject to central control by the Environment Agency under IPC and are known as Part A processes. Part B processes, which involve the emissions of prescribed substances only to the atmosphere, are controlled by the local authority. In either case, it is a criminal offence to operate a prescribed process without the necessary authorisation, or in breach of any of the conditions of the authorisation. Authorisations are reviewed every four years and require tight environmental standards to be met by means of upgrading programmes. The cornerstone is an obligation to employ BATNEEC - best available techniques not entailing excessive cost - to minimise or render harmless emissions to the environment.

The APC and IPC control regimes are now well established and many companies will have completed their upgrading programmes to achieve full compliance. Few textiles companies are subject to IPC, but some raw wool scourers with pesticides in their effluent and shrink resist processors with chlorine-containing discharges are affected, plus a number of other minority sectors. Larger numbers are regulated under APC, including many textile finishers.

Integrated pollution prevention and control (IPPC)

A new European directive called Integrated Pollution Prevention and Control (IPPC) will shortly necessitate changes to these UK control regimes. Fortunately, much of it is broadly similar to the APC and IPC regimes with which we are familiar, but there are certain important differences. The Government issued a consultation paper last summer and a second one in January 1998 to seek views as to how IPPC should be implemented into UK law. One obvious, and potentially far-reaching, difference is that IPPC requires BAT rather than BATNEEC - there is no explicit requirement for the environmental regulator to consider the affordability of an environmental protection measure for a particular industrial sector, and in particular its costs in relation to the environmental benefits it will produce - as is currently the case. The plan is to phase the sectoral affordability test out gradually as information becomes available on the costs and benefits of different environmental protection measures in the various sectors subject to IPPC.

THE ENVIRONMENT ACT 1995

The Environment Act 1995 (EA95), which received Royal Assent in the summer of that year, introduced a number of changes of relevance to the industry. It created the Environment Agency, formed from the merger of Her Majesty's Inspectorate of Pollution, the National Rivers Authority and the 83 English and Welsh waste regulation authorities, two years ago in April 1996. A similar, north of the border, body, the Scottish Environmental Protection Agency, was created at the same time. Since the change in government last year, the Environment Agency has come under pressure to "get tougher" with polluters.

The EA95 also introduced a new contaminated land regime and greater powers for the two environmental protection agencies to prevent water pollution by issuing works notices (see below). Many textiles mills, while operating to modern environmental standards, are situated on land which has been in industrial use for many decades and the possibility of historic contamination cannot be ignored. The new contaminated land provisions reinforce the "polluter pays" principle and mean that companies could be forced to clean up sites which they contaminated in the past. In the absence of the polluters (because the individuals have died or companies have been dissolved), the current owner or occupier of a site can be made to remediate the contamination. It is this which has made banks particularly wary about the new regime since a secured lender which enforces its security when the borrower defaults could pick up any clean-up liability which attaches to that property.

It must be emphasised that, although the above seems alarming, it is only the most contaminated sites which will be affected.

Water pollution offences

At present, the environmental regulators have limited powers to use against polluters of land. Unless the contamination has been caused by illegal waste disposal, or water pollution is being caused, or the land is in a state which makes it a statutory nuisance, no offence is being committed and the polluter cannot be made to clean up the site. (Of course, if the contamination is affecting a neighbour or his property, that neighbour may have a civil claim against the polluter, but such actions are expensive to bring, often difficult to prove, and therefore rare.) In practice, only if the land contamination is seeping into a nearby watercourse or groundwater beneath the site is there any real risk of enforcement action, and in such situations the Environment Agency is not afraid to bring prosecutions and use the threat of such action to make the original polluter, or the current owner of the site, clean up the contamination. Under the Water Resources Act 1991, a criminal offence is committed by anyone who "causes or knowingly permits" pollutants to enter water, and therefore an "innocent" landowner who knows about the contamination but does nothing to stop it entering water is just as liable to prosecution as the person or company who polluted the site in the first place.

If the "causer or knowing permitter" refuses to remediate contamination which is polluting water - and that is unlikely when faced with a prosecution as co-operation with the Agency will be useful mitigation - the Agency currently has the power to carry out the necessary works itself and recover the cost from the "causer or knowing permitter". This power has only rarely been used, as cost recovery through the civil courts is by no means assured of success and the Agency has limited funds.

Once the works notice provisions of the EA95 come into force, the Agency's hand will be further strengthened. It will be able to serve a works notice on the "causer or knowing permitter" of water pollution, specifying the investigatory, monitoring or remedial works necessary and giving a timescale. If the requirements of the notice are not met, the recipient is liable to prosecution and, on conviction, a large fine and/or imprisonment. The EA95's works notice provisions amend the Water Resources Act 1991 and are expected to take effect, through new regulations which have so far only been issued in draft form, during 1998. As they are relatively straightforward and easy to use, we may expect to see the Agency making effective use of them wherever it finds water pollution. This may be when a spillage or leak of fuel oil or acid, for example, is threatening to enter a watercourse, or when historic contamination on a part of the property is slowly leaching into the aquifer below. Such clean-ups can be exceedingly expensive and, these days, will often not be covered by insurance.

Contaminated land regime

Another part of the EA95 which is not yet in force are the remediation notice provisions which will amend the EPA. It will become much easier for the regulatory authorities to take action when contaminated land is causing a problem, even when water pollution is not involved.

The Act contains the following features in relation to clean-up liability:

1 A definition of contaminated land.

2 Clean-up provisions, which include a definition of "remediation" and provide for the service of a "remediation notice".

3 A definition of who can be required to carry out the clean-up (an "appropriate person").

4 A mechanism for recording remediation requirements and details of the measures taken on publicly accessible registers.

Definition of contaminated land

The new definition of contaminated land is as follows:

"any land which appears to the local authority in whose area it is situated to be in such condition, by reason of substances in, on or under the land, that -

a) significant harm is being caused or there is a significant possibility of such harm being caused; or

b) pollution of controlled waters is being, or is likely to be, caused... "

In all cases, the harm/pollution must be attributable to substances present in, on or under the land. Note that there does not have to be *significant* harm, or a *significant* possibility of such harm, where pollution of water is concerned.

In summary, land is contaminated within the legal definition if it is actually causing a problem, or if it is at least likely to do so. It is clear that many sites which are currently regarded (by purchasers, at least) as contaminated would not fall within the EA95 definition. In general, only the worst sites will be affected, eg. unremediated gas works, landfills full of putrescible or toxic waste, etc. Even then, such sites may not pose any real threat to the environment if they are not near water and the contamination on them is not causing any harm where it is and is not likely to move.

Identifying contaminated land

Once these new provisions come into force, local authorities will be under a duty to inspect the land in their areas to identify contaminated sites. To do this they will have to decide whether land comes within the legal definition of contaminated land. In reaching their decision, the council officers are bound by detailed guidance from the DETR (which has already been issued in draft). They must have some evidence before classifying a site as contaminated - suspicion or conjecture is not enough. This evidence could derive from inspecting existing reports and other documents which detail the site's condition, or it could mean that the council has to commission its own survey of the land to confirm a belief that it has become contaminated. They must reach a carefully considered view of the matter, and they must be able to justify their decision.

The guidance waters down the definition of contaminated land. It makes it clear that land should not be so designated unless the contamination means it is unsuitable for its current use. Harm to human life should be considered in relation to the current occupiers and neighbours (so, if this is an isolated site, it may be that harm to people can be disregarded altogether). The same applies to harm to property - it is only the present use of the land and other land which it may affect which counts. Harm to ecosystems should be ignored unless they are protected ecosystems under the Wildlife and Countryside Act 1981 or various EU directives.

It seems unlikely that local authorities will commission many environmental site investigations from consultants as they cannot afford it. Neither do they have the expertise or resources to do the work themselves. They will not normally be given access to environmental reports which site owners, or former owners, may have had done. It would seem that the risk of any particular contaminated site being designated "contaminated" is low unless it is generally known in the locality that it is polluted or the contamination causes problems which come to the attention of a regulator.

Where the harm, or the pollution of water, or the risk of either, is "serious", or of a type in which the Environment Agency has particular expertise, then there is provision to designate the site as a "special site". The Agency will have control over special sites, rather than the local authority.

The clean-up liability

Anyone (including companies and other bodies) who caused or knowingly permitted the contaminants to be present on the site could find themselves liable for that contamination and forced to clean it up. These are known as Class A persons, but they will not be responsible for remediating contamination which they did not cause or knowingly permit.

Note that the "causers" and the "knowing permitters" are potentially equally liable, although the guidance which is in draft form includes complicated rules for excluding some of these parties and apportioning clean-up costs between those who are left. If no causers or knowing permitters can be identified after the local authority has made reasonable enquiries, then anyone who currently owns or occupies the site could be liable for clean-up. These are called Class B persons. The current owner or occupier will be liable for the balance of the contamination where the parties responsible for some contaminants, or some polluting events, have not been found. For any given site, there may be a number of parties (eg. current and former owners) who could be forced to pay all or a portion of the clean-up costs, and these are known as "appropriate persons".

"Causing" and "knowingly permitting" are familiar terms in environmental legislation. Causing is a strict liability offence - no intention to pollute is necessary and it does not matter whether or not the polluter is blameworthy, whereas "knowingly permitting" requires both knowledge and the ability to prevent the pollution.

An owner is defined as "a person (other than a mortgagee not in possession) who, whether in his own right or as a trustee for any other person, is entitled to receive the rack rent of the land, or, where the land is not let at a rack rent, would be so entitled if it were so let". A tenant on a short lease is therefore not an owner, but would normally be an occupier. Lenders are particularly wary about the additional clean-up liabilities brought in by the Environment Act because clean-up costs can be far in excess of the value of their security. It is clear that an "innocent" former owner, who neither caused nor knowingly permitted, will not be liable for clean-up.

Importantly, the draft guidance states that the exclusion/apportionment tests must be carried out without regard to whether or not any of the "appropriate persons" concerned would be able to bear the costs themselves, would benefit from any insurance or other means of transferring the responsibilities, or would be subject to a limitation of costs under hardship provisions in the EA95.

Liability is limited with respect to pollution of controlled waters. Where land is only contaminated by reason of the fact that pollution of controlled waters is being or is likely to be caused, there can be no Class B person. Instead there are parallel powers under the Water Resources Act 1991 (see above)

The draft guidance has identified a number of tests to exclude and then apportion liability in certain circumstances. In relation to those initially identified as Class A "appropriate persons", seven criteria have been identified to be applied to exclude members from the group. These include where payment has been made by one member of Class A to another. For example, if somebody is given a discount when they purchase land because it is contaminated, the local authority is entitled to take this into account when looking at the liability of any person falling into Class A. Where two or more people are identified in Class A, and one member does not appear to be effectively in control of the relevant act or omission leading to the pollution, they will be disregarded. The guidance indicates that this would apply, for example, to a person who is only a member of Class A by virtue of providing financial assistance to another Class A member, leasing land or otherwise licensing the occupation of land to another member, or underwriting an insurance policy.

In relation to Class B members, where there are two or more persons identified as being either owners or occupiers, the local authority is to exclude all those who appear to be liable to pay a rent equal to the rack rent for such of the contaminated land as occupied and to hold no beneficial interest in the ownership of the land. The expression "beneficial interest" is square bracketed in the draft guidance, and is unclear in meaning but one assumes that the intention is to ensure that the extent of liability will depend on the precise terms of individual leases and that liability for remediation goes with the capital interest in the land.

Public registers

Appropriate persons, as well as the current owner and occupier, will be informed when a site is designated as contaminated. No entry is made on a public register at this stage. A consultation period then commences which lasts at least three months - unless there is a serious threat to the environment which necessitates faster action. During this period the regulator will consider whether remediation can be carried out at reasonable cost, compared with the seriousness of the harm to the environment if no action is taken. If so, it will seek to come to a voluntary arrangement with the appropriate persons to remediate the site. But if a negotiated solution cannot be found, then a remediation notice will be served specifying exactly what is to be done and by when.

Remediation notices are entered on a public register. Failure to comply with a notice without reasonable excuse is an offence, punishable by large fines (up to £20,000 in the Magistrates Court), and the regulator is then able to carry out the clean-up itself and recover the costs from the appropriate person(s). The means of recovery include taking a charge (mortgage) over the land. Details of the site and the remedial actions taken will be recorded on the register once a remediation notice is served. Inevitably, this may mean that the site becomes blighted. If a voluntary clean-up agreement is reached, without the need for a remediation notice, then a "remediation statement" will instead be placed on the register. Similarly, if the regulator feels that the cost of remediation would outweigh any benefits to the environment, it will instead issue a "remediation declaration" stating why it has come to this decision.

The Government's policy is that contaminated sites should only be remediated to a "suitable for current or proposed use" standard.

Compensation for "innocent" landowners

Clean-up liability could attach to a former owner or occupier who no longer has access to the property. In this situation, the EA95 requires that persons whose consent is required (eg. the current owner) should grant the necessary rights to allow the appropriate person(s) to comply with a remediation notice. The grantor can claim compensation from the person who has received the remediation notice. It is possible that "innocent" owners of contaminated land will be forced to allow time-consuming and disruptive remedial works to be carried out by former owners. The basis on which compensation can be claimed will be prescribed by regulations. As yet we do not know whether, for example, loss of profits would be recoverable where the business activity has had to be interrupted to effect the clean-up.

OTHER PROPOSED AND RECENT CHANGES IN LEGISLATION

There are myriad other changes in the law which are affecting textiles manufacturers, including obligations to recover packaging waste, new requirements for oil storage and the introduction 18 months ago of a landfill tax and more stringent special waste regulations.

Landfill directive

The landfill tax was introduced in October 1996, and will rise to £10 per tonne for non-inert waste from April 1999. At around the same time in the autumn of 1996, new Special Waste Regulations came into force which meant additional disposal costs for businesses producing special wastes. An EU directive will mean further increases within the next few years.

The Landfill Directive will introduce a number of restrictions on the disposal of waste to landfill once it is implemented in UK law. These restrictions, while not directly affecting textiles companies, will undoubtedly increase the cost of waste disposal. The main effects will be:

- A reduction in landfilling of biodegradable waste. Taking 1995 as the base year, the reduction in the UK has to be 25% by 2010, 50% by 2013 and 75% by 2020.

- Pre-treatment of waste before landfill. The intention is reduce the volume of hazardous waste. The pre-treatment could take the form of physical, chemical or biological processes, including sorting, that change the characteristics of the waste in order to reduce its volume of hazardous nature, facilitate its handling or enhance recovery.

- A ban on the disposal of used tyres. Whole tyres will be banned within 2 years and shredded tyres within 5 years.

- Other bans. There will be a ban on the disposal of liquid waste unless it is inert, and on the disposal of waste which in a landfill would be explosive, corrosive, oxidising, flammable or is clinical waste.

- Increased cost of landfill. Prices charged should cover the setting up, operation, and cost of financial security, the estimated cost of closure and aftercare for at least 50 years.

- A ban on the co-disposal of hazardous and non hazardous waste. This would lead to increased disposal costs as some waste would have to be diverted to specially engineered landfill, incineration or solidification.

- Standard requirements introduced. These include the minimum distance from residential areas, surface sealing of the site, prohibition of the spreading of dirt from the site on public roads, fencing and control of access in order to avoid illegal dumping. The UK already has higher standards than these in some cases.

- Stricter provisions for existing sites. These include provisions on the collection, treatment and use of landfill gas.

Oil storage regulations

The Government consulted on these regulations last year and we may see a second consultation paper before the issue of the final regulations. New oil tanks above a certain size will have to include secondary containment to reduce the risk of water pollution in the event of a spill or leak. The Environment Agency will also be able to require improvements to existing installations if it considers that they pose a significant pollution risk.

The Solvents Directive

Another directive, the Solvents Directive (full title: directive on limitation of emissions of volatile organic compounds due to the use of organic solvents in certain industrial activities) will have implications for some textiles companies. The proposed directive was published in the Official Journal in March 1997. Again, it must be implemented into UK law before it has direct effect, but the draft requires that to be done by the end of next year. The proposed directive sets stringent emission limits (including fugitive emissions) for certain organic solvents and bans others except in limited circumstances. Those in the latter category are solvents which are carcinogenic, mutagenic or toxic to reproductive processes. Solvent use in textile coating processes and dry cleaning will potentially be affected.

Packaging waste regulations

The Producer Responsibility (Packaging Waste) Regulations 1997 came into force last year to implement another EU directive. Many businesses handling more than 50 tonnes per year of packaging are affected, although packaging which will not end up in the European Union (ie. because it is protecting goods which are being exported to other markets) is not counted. The rules are somewhat complex, but affected companies must ensure that a proportion of the packaging handled is recycled or recovered, or must join a compliance scheme which takes the responsibility for doing so. 1998 is the first year that the recycling/recovery targets have applied, although businesses needed to register with a compliance scheme or the environmental agencies directly by last August.

Economic instruments

This government appears to have a fondness, at least in theory, for the use of economic instruments to back up regulation as a means of meeting environmental standards and achieving improvements. A consultation paper released in late 1997 considered the use of economic instruments for regulating water pollution, in addition to or even instead of the existing statutory control regime of consents to discharge effluent to controlled waters.

The two main possibilities are tradeable permits and charges which, like those for discharges to sewer, reflect the pollution potential of the effluent stream. Other ideas discussed include such things as taxing pesticides to encourage users to be less profligate with them. Although tradeable permits have worked very well in some environmental scenarios, they are less suitable for use in the water medium than for atmospheric discharges and changes to the system of charging seems the most likely option to be endorsed. One of the effects of this, for those discharging to a sewage treatment works operated by a water company, is that the water companies are likely to introduce charging schemes for their customers which reflect the "hard" pollution in the effluent which remains after treatment and so affects the charges levied on the discharge from the treatment works. These changes, even if they are accepted by the Government, are several years away but it would be sensible for those with "difficult" effluents to monitor the progress of this consultation exercise. Persistent substances in textile effluents, which are still present at the outfall of the sewage treatment works, will mean high charges for the water companies which will surely be passed on to their customers.

Other economic instruments which have had a mention during the last few months include tradeable carbon dioxide permits as a means of meeting the Kyoto Summit levels, a tax on greenfield developments and the tradeable packaging recovery notes (PRNs) created by the packaging waste regulations.

CONCLUSIONS

UK textile companies will need to keep a watch on forthcoming developments in environmental law. There will be changes affecting current operations (eg. IPPC and the oil storage regulations) and past operations (eg. remediation notices) which have the potential to involve capital expenditure and must therefore be planned for. Much of the new legislation has its origins in Brussels and will therefore affect companies in other Member States too.

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WASTE ELIMINATION FROM TEXTILES

M.J.C. Hewson

INTRODUCTION

The issue of waste elimination is of particular importance within the textile sector of industry, where production processes exhibit a high demand on energy input and resources on the one hand and create aqueous effluent streams with high biological and chemical oxygen demand, suspended solids and colour as well as high volumes of solid waste on the other hand. The generation of waste streams presents many issues and opportunities for industry. Current trends indicate that future changes in legislation relating to waste will inevitably increase costs for disposal and provide incentives for waste minimisation. Even the most efficient of companies produce waste, with the true cost being as high as 10% of business turnover. Any reduction in waste goes straight to the bottom line.

The overall aim of any waste elimination strategy is to address and exploit opportunities presented by waste within the organisation through the identification of existing or new practical waste management techniques which will improve competitiveness, and subsequently that of the textile sector as a whole. Standards of achievement need to be set against which other similar achievements can be measured or assessed, i.e., benchmarking.

ESTABLISHING A WASTE MINIMISATION INITIATIVE

Waste minimisation should not be considered as a one-off event but an on-going process of continual improvement. In this sense it is analogous to Total Quality Management (TQM) and many of the tools and techniques of TQM can be equally effectively harnessed for waste minimisation/elimination. Any initiative on waste minimisation will need to address raw material use; water and energy consumption; effluent generation; product losses and generation of other waste streams. Benchmarking is a continuous, structured, analytical process, which identifies, adapts and adopts the best practices that lead to superior performance within an organisation. It refers to the highest standard that has been achieved. In reality benchmarking can be used to make comparisons with competitors and other industries; highlight best practice; focus on key elements of the business, and make a comparison of all organisational functions. If carried out in a logical manner benchmarking can result in significant benefits, which include:

- Increased customer satisfaction
- Reduction in operating costs
- Reduction in lead times
- An increase in added value
- Improving on other's techniques
- Learning from other's mistakes
- Increased technological awareness
- Improved operational effectiveness
- Reduction in rejects and reworks

BENCHMARKS

There are a number of key environmental benchmarks, which cover all aspects of textile processing. Because of the nature of the sector most are directed towards wet processing which tends to be the most environmentally unfriendly sub-sector.

Process Energy and Water Usage Ratios

An important area especially in wet processing and typical ranges are:

• Woollen/Worsted	100 – 120 GJ/tonne	3 – 150m^3 water/tonne
• Cotton spinning	60 – 90 GJ/tonne	
• Cotton weaving	10 – 50 GJ/tonne	1 – 5m^3 water/tonne
• Textured yarn	5 – 50 GJ/tonne	
• Textile finishing	10 – 150 GJ/tonne	5 – 200m^3 water/tonne
• Carpet sector	25 – 100GJ/tonne	3 – 90m^3 water /tonne
• Miscellaneous	2 – 80GJ/tonne	

The ranges given for both energy and water usage are typical, but because of the nature of the textile processing there will always be extreme examples outside these values. Either the product specification, the use of old machinery or just poor control systems usually explains these. Experience has shown that because of the nature of textile processing it is difficult to pigeonhole companies and draw up league tables of performance based on energy and water usage. More often than not each process has to be assessed based on the type and age of machine and the processing constraints after which energy and water savings can be introduced and shown to be beneficial.

Effluent Treatment Technologies

The size and location of most textile processors still means that the vast majority undertakes little or no on-site treatment apart from pH adjustment and balancing. It is estimated that no more than 5% of companies operate their own effluent treatment either because they are discharging to river or because of the presence of particular 'nasties' in the effluent requiring some form of primary treatment. For aqueous treatments the technologies employed are typically physical, chemical or biological in nature. Where solid waste becomes significant the emphasis changes to one of solid waste elimination or minimisation before treatment systems are considered. The main options open for waste solid management are recycling, incineration or landfill.

If colour is a significant problem then wet processors generally opt for some form of chemical flocculation treatment followed by settlement or dissolved air flotation. However, there are problems with this approach with certain dyestuff classes and the process of flocculation itself can be disturbed by the presence of certain chemical auxiliaries e.g. non-ionic detergents. Alternative procedures involve some form of assisted oxidation, which is not usually considered cost effective.

The more general mixed effluents, including preparation and finishing discharges may be more amenable to biological treatment. However, there are very few sites with the available space required to locate such a plant, and there is an element of expertise required in operating such a system. One sector where biological treatment is the primary option is wool scouring which produces an effluent with high BOD and COD. More specialist biological technologies such as anaerobic digestion, bioscrubbing and biofiltration are finding specific end uses within the industry although they tend to be employed as a tertiary treatment where aqueous discharge to a river is practised. Such technologies tend to function better on constant relatively low polluting load effluents but some form of pre-treatment is still required. Membrane technology has been the subject of much interest and successfully employed using ultrafiltration methods to remove pesticides from wool scouring effluent and recycling of water.

Dyestuff Fixation Levels

Table 1: Dyestuff fixation levels for textile dyes

Dye Class	Fibre Type	Degree of Fixation %	Loss to Effluent %	Benchmark Fixation Level %
Acid*	Polyamide	80 - 95	5 – 20	90
Basic	Acrylic	95 - 100	0 – 5	97
Direct	Cellulose	70 – 95	5 – 30	85
Disperse	Polyester	90 – 100	0 – 10	95
Metal Complex	Wool	90 – 98	2 – 10	94
Reactive*	Cellulose	50 – 90	10 – 50	70
Sulphur	Cellulose	60 – 90	10 – 40	75
Vat	Cellulose	80 - 95	5 - 20	90

*Some acid and reactive dyestuffs, which cannot be successfully treated, retain residual colour at the point of discharge.

The major concern with colour is its aesthetic properties at the point of discharge with respect to visibility in rivers. Colour consents are now being enforced thus dye fixation levels are becoming more important. Typical fixation levels are shown in Table 1 for most of the dye classes with recommended benchmark figures for each class. Selection of the most appropriate dye reduces the effluent losses but there is depth of shade to consider which influences the extent of dye loss. Much work is being undertaken to increase the degree of fixation which whilst improving the colour discharge problem will in addition reduce the dyestuff requirements per kg fabric dyed.

Raw Effluent Characteristics

The typical effluent characteristics for four specific types of processing are shown in Table 2 together with current legislative consent limits for discharge to watercourse and sewer.

Table 2: Raw effluent characteristics for aqueous textile processing effluent

Parameter	Wool Scouring	Woven/Knitted Fabric Finishing	Stock and Yarn Dyeing	Carpet Mill	Typical Consents River/Sewer
PH	8 - 10	7 – 9	5 - 9	6 - 8	†/6 - 9
Temp. °C	30 -40	30 –40	25 -50	30 -40	†/42
COD mg/l	5 – 35000	100 – 1000	800	1 - 4000	*/*
BOD mg/l	20–60000	50 – 400	250	300 - 1200	20/*
S.Solids mg/l	1 - 20000	50 – 150	100	120 - 180	30/*
PCP	-----	2 – 100	-----	-----	1 – 6 μg/l
Permethrin	-----	-----	-----	0.2 - 10	10 – 20 μg/l
Lindane**	0 -5	-----	-----	-----	0 – 1 μg/l
Am.N_2 mg/l					5

* No specific limits. ** Includes aldrin, dieldrin and diazinon. † Specific conditions apply

The characteristic values for fabric finishing, dyeing and carpet mills are similar. However, the wool scouring effluent is for certain parameters considerably more heavily loaded. In terms of effluent treatment technology and waste minimisation wool-scouring effluent is treated separately. Apart from colour the main consented pollutants are pentachlorophenol (PCP) in cotton processing and pesticides in wool scouring and carpet production. PCP a rot-proofing agent added in developing countries to grey fabric to protect it in storage and transport has been subjected to strict legislative control and levels in imported cloth are on the decrease although occasional high levels are still observed. Historically wool scourers have experienced problems with 'drins' (Aldrin, Eldrin and Dieldrin) from sheep dip treatments. However, better control of their use has led to a significant reduction of the drins in discharge to rivers. Wool carpet manufacturers are also severely restricted in the discharge consents for the continued use of the moth proofing agents' permethrin and cyfluthrin. Uncontrolled small amounts of these toxic materials still find their way into rivers. The very low consent levels imposed upon the industry have forced them into looking at either pesticide 'add-on' techniques using closed loop systems thereby eliminating any toxic discharge or employing ultrafiltration treatment of effluent before discharge.

Recycling of Water – Quality Limits

The textile industry remains one of the heaviest consumers per tonne of product and thus the recycling of water is of major interest. However, the quality of the water for reuse is an important factor when considering its potential. Water quality requirements for reuse have been found to be less stringent than for discharge. Dissolved solids can be accepted up to 500mg/l, metal content up to 0.1mg/l, colour as high as 30AU and hardness up to 80mg/l. For less demanding processes such as initial rinsing/washing off more contaminated water could be used requiring minimal or no treatment to satisfy the processing criteria. Counterflow washing procedures, reduced liquor to fabric ratios and minimum add-on chemical finishing have all contributed to an initial reduction in the use of water for textile processing.

Air Pollution - Consent Limits

Emissions to atmosphere have as a consequence of the Environmental Protection Act of 1990 been severely restricted and consent limits for the textile industry are published in a sector specific process guidance note. The consented emissions are:

- Volatile Organic Compounds (as total carbon) — 150 - 400mg/m^3
- Total particulate Matter — 50mg/m^3
- Carbon monoxide from incinerators — 100mg/m^3
- Isocyanates (expressed as NCO) — 0.1mg/m^3
- Formaldehyde — 20mg/m^3
- Nitrogen oxides from incinerators — 300mg/m^3
- Ammonia — 30mg/m^3

This legislation has encouraged a move away from the use of volatile organic compounds in printing and certain coating processes. There has also been a gradual introduction of 'low' formaldehyde finishing processes and the optimisation of processing which reduces the emission of formaldehyde without compromising product quality.

Process modifications and the assessment of chemical auxiliaries and their subsequent use is considered the most appropriate route to minimising waste production. However, where emissions are still found to be in excess of the limits the preferred remedy for stenters, bakers and curing ovens in the introduction of a appropriate scrubbing device linked to a heat exchanger and an electrostatic precipitator. Thermal oxidation as well and cryogenic condensation processes are also options but tends to be more expensive.

Fibre/Fabric Production and Packaging Waste

Waste fibres yarns and fabric are produced in all sectors of the industry. It is usually policy, especially during the earlier stages of processing, to reuse waste fibre and yarn. Depending on the type and condition of the waste it can be either directly introduced into the process line or sold on to a waste merchant for a variety of uses. Waste fabrics are a little more difficult to recycle. Wool and acrylic can be pulled and resold as coloured fibre for blending and use in lower quality goods. Cotton, however, can only be sold on as rags or for use as filling materials. The other major outlet for waste is second hand garments which are either sold on in charity shops or exported to Third World countries. Waste man-made textiles are now being considered as a potential source for recovery of the base polymer by depolymerisation processes. Figure 1 indicates the amount of wastage that can be expected from various processing stages.

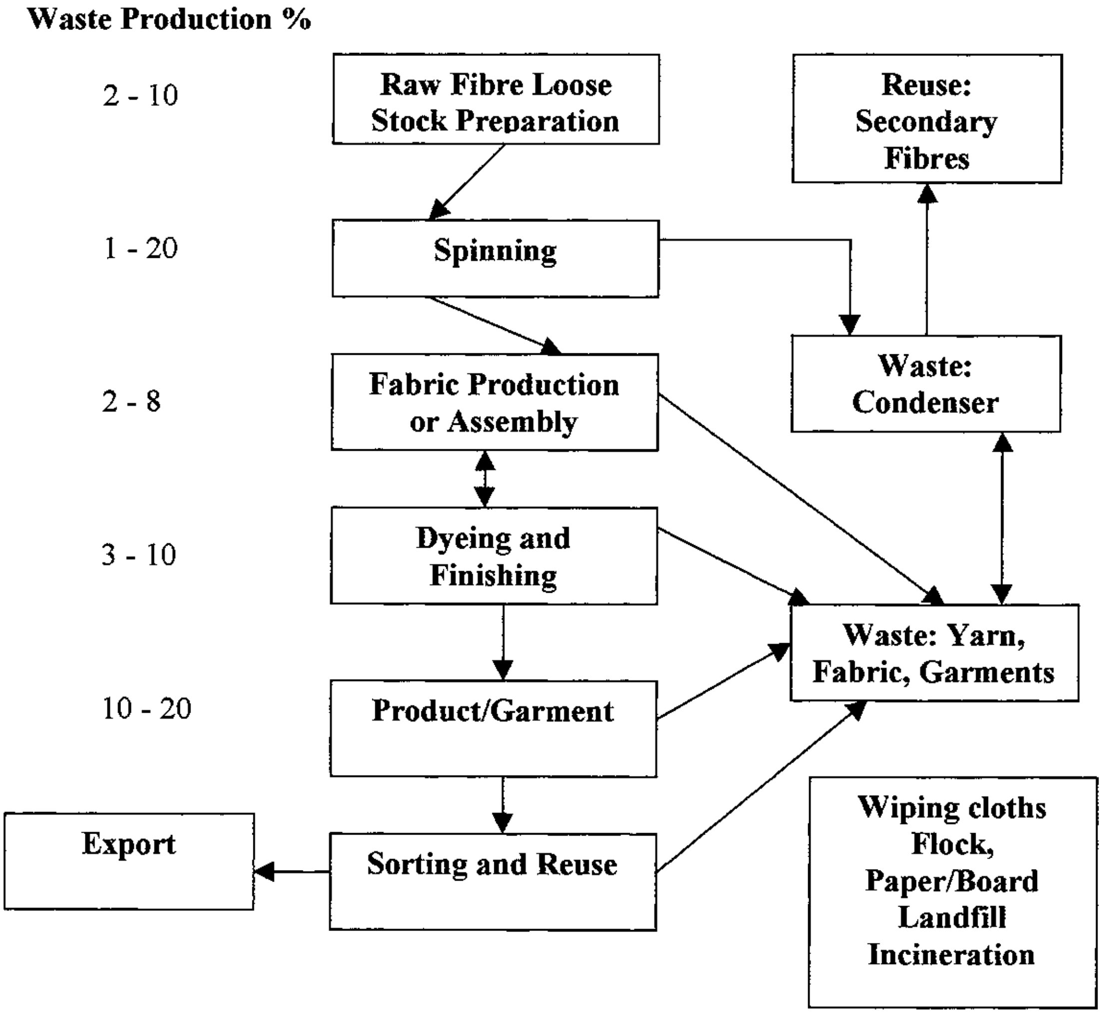

Figure 1: Fibre/Fabric Waste Production

Other solid waste, which is produced, includes cardboard and plastic packaging material, which can be segregated and sold on, and cones for yarn packaging which can be reused or recycled. Chemical usage is associated with bulk storage of non-returnable empty containers. There has been a considerable shift to using recyclable containers.

WASTE MINIMISATION IN PRACTICE

A recently completed short-term project involving eight participating companies has already realised savings of the order of £370,000 with a potential for more than double this if all the recommendations are implemented. This saving alone is equivalent to an increase in turnover of more than £12 million. The total potential savings in terms of reduced waste have been identified as:

- 42 tonnes less of solid waste to landfill
- 5 million kWh reduction equivalent per annum
- Elimination of 170,000m^3/year of demand for water
- Elimination of 900m^3 per annum of liquid waste for off site disposal.

In terms of specific savings the following case studies show where savings have and can be made and the benefits generated by the participants in reduced waste and cost. The companies involved were drawn from all sectors of the industry and as such represent a typical cross section of spinners, weavers, finishers and makers-up.

Reduction in utilities

This may seem obvious but a significant number of companies' still take energy/water minimisation for granted and consider potential utility savings to be minimal. Closer inspection of steam raising at one company identified 52 passing steam traps, a number of leaks and significant sections of poorly lagged pipework. Repairs resulted in 10% savings on consumption. A water audit of this site showed a significant discrepancy between metered and used water. This resulted in an identification of a major leak in one of the departmental supply lines and just over 10% was saved. Electricity savings were also made by installing power factor correction equipment (£24,000 capital cost resulting in £7,000 annual savings) and promoting a 'switch off' campaign. Overall savings are estimated as being approximately 2%.

Reduction in packaging waste

Cardboard bulk containers were used to transport and store threads at different stages of processing. The boxes were relatively flimsy and were destroyed after only one trip around the site resulting in an annual replacement cost of £45,000. Plastic containers with a ten-year life span were bought at a one off cost of £135,000 and after an initial payback of three years the annual saving are about £30,000.

Reduced slippage of yarn during winding

Incorrect tension during winding caused 'sloughing' and a loss of more than 100kg of yarn per week. An investigation of the machinery set up during winding showed variations in the tension at each winding position. After tests to optimise operational parameters a standard tension was agreed upon. Sloughing was significantly reduced and together with annual savings of £25,000 a noticeable improvement in the overall standard of the finished product was observed.

Reduction in cloth waste during printing

Fabric losses during preparation, print set up and bulk printing accounted for 9% of the total throughput. A quality system was introduced to implement corrective and preventative actions to reduce these losses. This consisted for set up purposes of a reduction in the trial samples from 40 to 10 metres; computer records for colour shades, mix and customer details, and correction of screen faults before bulk printing. At the bulk printing stage fabric check lists are in place at each machine; all production is subjected to quality inspection; all quality reports are reviewed daily and stored on an IT system. For repeat orders information on the three previous print runs are reviewed to prevent any repeat faults and the printing schedule for the next three days is discussed as part of a rolling programme. There were no implementation costs involved but it required additional management time and effort. Waste levels were reduced by 3% with annual savings of £76,000.

Chemical recycling

Re-using some unexhausted desizing liquors made small savings in chemical use and effluent discharge costs, amounting to about £6,500. An attempt to reuse liquors on bleaching machine was made but the quality of the fabric was significantly effected and so this practice was stopped.

Print screen recycling

Printing screens normally manufactured in-house from fine nylon mesh on a metal frame are stored to avoid repeat screen production. All screens not used in the past 18 months were identified, customers contacted and future requirements assessed. If the design was no longer required the screen could be refurbished and recycled. About 2,000 screens per year are now recycled instead of being stored, with savings in excess of £25,000 per annum.

Print paste savings

Even when using a standard colour controlled blending operation that accurately controls colour strength the amount required on a fabric can still vary by as much as 25% due to colour uptake inconsistencies. Consequently there is invariably a significant colour return on most runs. Over production runs into 100's of tonnes per year. A sophisticated re-weighing and colour matching system that reuses all colour returns of 5kg or more would make estimated savings of nearly £70,000 per annum at a cost of just over £60,000. A decision has not yet been made.

Bleach machine heat recovery

Two washing ranges on the bleaching machine were fitted with their own heat exchangers but they were found to be plumbed in co-current rather than counter current. This reduced their efficiency significantly. However, it was decided to link the two washing sections and do away with the heat exchangers completely. This saved nearly

£16,000 in water and energy costs and the expenditure was only £3,000 for pipework to form a closed loop system.

Maintenance purchasing

Stocks of spares are usually maintained at a relatively high level and are obtained from long established suppliers. A reassessment of the maintenance purchasing policy emphasised the need for acquiring replacements on short delivery times, identifying new suppliers at lower prices and by reducing stock levels to a minimum. Maintenance and replacement part ordering details were linked with individual machines and stored on a computerised system. For a medium sized company savings of the order of £77,000 per annum were achieved.

Reduction in plastic tube use

Plastic tubes used for winding yarn onto eventually become damaged leading to over 1000 per week being disposed of. A combination of rough machinery parts and rough operator handling was established as the route cause. Replacement of rough parts and retraining of the workforce led to a reduction of over 90% on breakage rate over a period of 3 months down to less than 95 broken tubes per week.

Elimination of cone end waste

Traditional operating methods left significant quantities of yarn on cones after spinning. This was often found to be over 3000 metres per cone and between 10 an 15 cones per job. All this yarn was scrapped. The operating procedures were changed so that identical cones are fitted to the spinning frames with the same length of yarn per cone. This has now been optimised such that a mere 10 to 15 metres of yarn are left per cone. This represents a 99.5% reduction in yarn waste at source with associated savings of £20,000 per annum. Any residual yarn is rewound on a machine, designed in-house and reused. No yarn now goes to waste.

CONCLUSIONS

The implementation of a policy aimed at eliminating waste from textile production can be successful as indicated from the representative case studies described in this paper. In any successful evaluation of waste and its subsequent management the following conclusions can made:

- The management of waste identifies economic financial savings and reduced waste generation.
- Emissions to the environmental media of land, water and air are reduced.
- Up to 40 % of the identified opportunities can be implemented over a short period of time.
- Up to 35% of identified opportunities to reduce waste are usually low cost/no cost opportunities.
- The generation of opportunities to reduce waste requires determination.
- Waste management does not stop but remains a part of continuous management.
- Interaction between companies with similar problems is advantageous.

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SUCCESS WITH ENERGY MANAGEMENT

M.J.C. Hewson

INTRODUCTION

Textile dyeing and finishing covers a wide range of treatments and processes used for altering the appearance and properties of textile products. The most basic of these are scouring, bleaching, washing, dyeing and drying and the textile may be in the form of a yarn, woven or knitted fabric or even the completed garment. The wide range of machinery and chemicals used to attain the different finishes makes it difficult to derive benchmark figures for the energy and water usage processes. Energy and water savings, however, tend to fall into distinct patterns and can be considered in the following main categories i.e. batch wet pressure, batch wet atmospheric, continuous wet, contact dryers, hot air dryers, and hot air or steam – heat treatment. Other processes of significance tend to be either a mixture of more than one type of the main categories or use exclusively electrical power only e.g., raising machines, looms, spinning frames etc.

The typical energy requirements of a number of common textile finishing processes are shown in Table 1. The energy levels quoted do not include generation, distribution or boiler losses and the wide variation in energy usage is the result of differing degrees of preparation required for the different types and qualities of textile, fabric weights, classes of dyestuff and finishes applied. The complexity of the processes should not stop the establishing of energy savings and a number of questions should be asked on how, when, where, and why energy is being used compared to how much energy should we be using and if we are using more why and how to do something about it. Energy is a controllable resource.

BATCH WET PROCESSING USING PRESSURISED VESSELS

These are typically kiers, jet-dyeing machines, beam dyeing machines and a variety of package dyeing vessels. Such machines are closed vessels typically heated indirectly by steam, so they do not suffer evaporative losses of energy. Typical energy consumption for a jet dyeing unit is of the order 1500GJ/year of which nearly half the energy in pressure dyeing vessels ends up in the cooling water, therefore, the reuse of this supply of warm water in some form of the processing is important. Water is discharged at temperatures as high as 60°C.

Most dyeing processes will cope with warm water up to about 50°C. The only problem arises with the correct sizing of an insulated storage tank and the provision for

Table 1: Typical energy requirements for textile finishing processes

Machine	Process	Energy (GJ/t)
Open Width	Scouring/Bleaching	3.0 – 7.0
Winch	Dyeing	6.0 – 17.0
Jig	Dyeing	1.5 – 7.0
Jet	Dyeing	3.5 – 16.0
Beam	Dyeing	7.5 – 12.5
Steam Cylinders	Drying	2.5 – 4.5
Stenter	Drying	2.5 – 7.5
Stenter	Heat Setting	4.0 – 9.0

an alternative supply if this source is fully consumed. In addition consideration should be given to dyehouse management and control systems which take the guesswork out of the dyeing cycle enabling blind or first time dyeing to be introduced reducing the re-dye percentage to an acceptable level. Lower liquor to fabric ratios are an obvious way to reduce both water and energy consumption. A project introducing a low liquor-dyeing machine instead of conventional equipment realised annual savings of £165,000 against an initial outlay of £94,000 giving a payback period of seven months. The benefits were recognised as:

- Reduction in steam requirement due to lower liquor to fabric ratio.
- Reduced water consumption and associated effluent charges.
- Reduction in the quantity of dyes and chemicals required.
- Reduced number of re-dyes and rejects from improved dyeing quality.

BATCH WET ATMOSPHERIC PROCESSING

These machines differ from the previous category in that they involve machinery in which evaporative losses are a significant proportion of the energy consumption. Typically they are of the type jigs and winches with energy consumption per unit of the order of 17,000GJ/year. The dye effluent accounts for 57% of the energy with the remaining attributed to evaporative losses. Typical aqueous discharge temperatures are of the order of 80°C.

The obvious actions to be taken are simply to install and use covers and hoods and to carefully control the operating temperatures. It becomes apparent what effect a slight change in temperature and the use of hoods can make to the overall energy consumption from the data presented in Table 2. For a jig with closed hoods operating at 95°C the energy consumption is only 15% of that required to operate at 100°C with the hoods open.

Effluent heat recovery offers a potentially high recovery of energy. Where large quantities of rinse water are employed there may be a need for the segregation of hot and cold flows, but even so the payback is generally still good. Heat recovery has been the subject of Good Practice Case Studies (GPCS). For example the installation of a plate heat exchanger to recover heat from a line of yarn dyeing machines cost £117,000 with energy savings valued at £53,000 per year. The system treated up to 4,000m^3 of effluent per week at temperatures up to 90°C and produced clean warm water at 40°C, which could be diverted to insulated holding tanks.

Table 2: Steam usage for Jig with varying temperature and operating conditions.

Operating Temperature °C	Steam Usage kg/hour Hood Open	Steam Usage kg/hour Hood Closed
80	50	23
90	61	28
95	73	34
100 (Simmer)	91	55
100 (Vig. Boil)	218	127

CONTINUOUS WET PROCESSING

This category applies to washing-off after preparatory processes such as scouring, bleaching and mercerising or washing-off after dyeing or printing. A continuous washing range is made up of a number of tanks connected by tension compensators and nip rollers. There is a wide variation in energy and water requirements for this type of process depending on the configuration of the tanks. For two different configurations employing either hot standing or counterflow tanks the energy requirement for the fully counterflow system is only 37% that for a standing tank system and the corresponding water consumption only 41%. If heat recovery is also introduced then the overall energy consumption can be reduced by a further 50%.

Initial savings on this type of unit are achieved by fitting covers on nips and tanks where the temperature is likely to exceed 60°C since nip evaporative losses may exceed 40% of the total energy input. Counterflow operation can sometimes produce the largest savings. In a typical conversion, a nine tank Mather & Platt continuous washer retro-fitted with a counterflow system for seven of the tanks realised over 60% savings in both energy and water usage without importantly any loss in washing performance.

An area, which is sometimes overlooked, is the wastage of water and energy during periods of idling. For longer stoppages with manual control the water flow will usually be turned off. However, with shorter stoppages the flow is left on and consequently a series of short stoppages can under certain circumstances account for a significant percentage of time for a given shift, maybe up to 20%. Automatic stop valves can be fitted which shut off the water flow as soon as stoppages occur and it is not uncommon for the cost of these valves to be recouped within a few weeks.

Effluent heat recovery and point-of-use water heating have been the subject GPCSs. Effluent heat recovery at a bleaching range employing a rotating element cost £10,000 to install and gave a payback period of one year. A washing range fitted with heat exchanger, gas fired cascade water heater and immersion tube burners replacing conventional steam injection in the wash tanks was installed at a capital investment of £48,000 and afforded an annual energy saving of just over £10,000. Payback was just over 4.5 years.

If all these savings were made it would still leave us with an inefficient method of washing as the current generation of washers have reached their technological limits. The basic requirements for the ideal washing range are shown in Figure 1. The main changes would be the large number of stages and the intimate contact between wash water and fabric. Development work undertaken at BTTG some years ago on a pilot scale washer proved that some form of pressure action would work but problems still exist in sealing the fabric edges to eliminate water leakage. If this basic design could be improved then there is considerable potential for this alternative way of washing.

- **Counterflow operation**
- **Wash water flow rate matched to washing requirements**
- **Large number of washing stages**
- **Washing parameters identical for each stage**
- **Wash water brought into intimate contact with textile**

Figure 1: Characteristics of the ideal washing range

CONTACT DRYING – STEAM CYLINDERS

Contact drying of fabrics using steam-heated cylinders is the simplest and considered the cheapest method for drying woven textiles and is mainly used for intermediate stages. Typical energy requirements are 2.59MJ/kg fabric of whom 52% is lost to evaporation and radiation, and convection accounts for a further 34%. A fabric may be dried down from 55% to 5% moisture content and even with this limited level of drying the evaporative losses are in excess of 50% of the total energy requirement. However, fabric is often dried down from 100% to bone dry, increasing evaporative losses to around 75% of total. Opportunities for savings start by investigating whether more mechanical pre-drying can be achieved.

Mechanical pre-drying can be in the form of mangling, centrifugal drying or even suction slot or air knife each with distinct advantages and disadvantages. Hydroextractors are by their nature batch dryers only, whilst the other methods are continuous techniques. The mangle in considerably cheaper but the suction slot is capable of lower water retention rates over a range of fabric types and it can be used to recover excess chemicals padded onto the fabric. A centrifuge, in terms of performance falls between mangles and suction slots, but because of the tendency to cause creasing is only used to de-water loose stock. Typical retention figures for a suction slot versus a mangle are shown in Table 3. The figures for mangles are generally worse than those quoted here. Thus the suction slot, therefore, usually out-performs the mangle in removing water, even for hydrophilic fibres, but costs nearly three times as must in running costs.

A demonstration project carried out at BTTG established the effectiveness the suction slot de-watering system. A 2.5 metre wide suction slot was retrofitted to the top of a pad mangle assembly. The slot a single herringbone pattern, with water separator and exhauster, cost £24,000 to install and saved over £115,000 per year. Most of the saving was as a consequence of an increase in turnover, because of the improvement in de-watering prior to drying. But even if we disregard this throughput effect, the payback for this equipment was still only just over one year.

Once alternative mechanical methods have been considered then there are often more simple operations, which can be undertaken to contact dryers to make them more efficient. These include obvious items such as the return of condensate from the machine, regularly checking steam traps to identify blockages and steam passing, and avoiding over drying of the fabric. On some wide sets of drying cans there may even be the opportunity to run two fabrics side by side to cut down on drying costs.

Table 3: Water retention mechanical pre-drying, Mangle vs Suction Slot

Fibre	**Mangle % Retention**	**Suction Slot % Retention**
Cotton	45 – 70	40 – 55
Viscose	60 – 100	60 – 80
Diacetate	40 – 50	27 – 40
Nylon 6.6	20 – 40	14 – 30
Polyester	20 – 30	10 – 16
Wool	58 - 60	35 – 55

HOT AIR DRYERS – STENTERS

The main method of drying is still hot air drying using stenters or tenters. This type of equipment has an important role to play. As well as being employed for drying fabrics it can be used for heat setting and curing, and the nature of the machinery means that processing affects the finished length and width and sometimes even the properties of a fabric. Stenters are heated in a variety of ways although nowadays most steam heated and thermal oil heated machines have been replaced by direct gas fired dryers. For a cotton fabric the energy requirement for drying down from 100% down to 6% moisture content is 6.2GJ/te. However, as much as 41% losses occur through evaporation and 40% via air heating. Thus fabric moisture content should be minimised before it enters the stenter and the exhaust airflow within the oven reduced.

Opportunities for savings are shown in Figure 2. Most modern machines would be delivered with automatic exhaust control and moisture measurement systems to minimise air losses and to avoid over drying. However, older machines still in use could be using as much as 30 to 40% more energy than is necessary. The introduction of more efficient pre-drying or even alternative drying techniques has been the subject of several demonstration projects. Installation of an infrared pre-dryer at £35,000 can save up to £22,000 per year in increased productivity and relative energy costs.

- **Introduce mechanical de-watering or contact drying or other techniques**
- **Avoid over drying**
- **Close off exhausts during idling**
- **Optimise exhaust air humidity**
- **Install heat recovery equipment**
- **Convert to direct gas firing**

Figure 2: Opportunities to saving energy - Stenters

Gas fired panels enable a stenter to operate at higher speeds and can increase throughput by as much as 50%, thereby, relieving production bottlenecks. If we compare this installation with the cost of a new bay for an existing stenter, then the cost would be about £45,000 and it would probably not have the same effect on throughput.

Radio frequency drying is used extensively for the drying and dye fixation of loose stock, packages, tops and hanks of wool and cotton. The energy requirement of radio frequency drying is approximately 70% that of a conventional steam heated dryer. However, its use is limited since it cannot accommodate knitted or woven fabrics because any transport mechanism, such as pins or clips would interfere with the RF drying field. For the installation of a new dyeing and drying line for the processing of loose stock wool savings of the order £190,000 per annum were realised for an investment of £350,000 giving a payback of about two years. The dye is padded on at very low liquor ratios and then dried through an RF dryer requiring no warm up time. The new range reduced energy, chemical and water usage and significantly reduced labour costs. Other benefits included an improvement in quality due to an accurate temperature control affording an elimination of shade discoloration and yellowing. An increased yield on the final yarn from carding and spinning was also observed.

At this stage mention is made of some recent developments in the field of drying technology, Airless Drying. A dryer has been developed for the batch drying of ceramics, and savings of about 80% on conventional drying have been made. The concept is that unlike conventional methods, which use airflow to carry away water vapour, airless drying prevents the inflow of air and re-circulates the moist air, recovering thermal energy and condensing the residual moisture. For the system to be cost effective the recovered heat from the condenser which is in the form of hot water needs to be used elsewhere in processing.

HOT AIR OR STEAM HEATING

This final category involves machines that either heat set, cure, bake or steam textiles. It is essentially not a drying process and, therefore, evaporation losses play a much smaller role. Typical energy requirements for heat setting are 4.66GJ/te with as much as 76% loss through air heating. Thus the minimisation of air losses is the most important factor. Nowadays because of the pressure from environmental legislation one of the major concerns of textile finishers is pollution control. The problem is usually in the form or particulate matter and volatile organics including formaldehyde and isocyanate emissions from stenters and is more commonly a problem with heat setting and curing processes.

Air exhaust is necessary to remove the volatile and particulate material from the fabric at high temperatures during heat setting, curing and dye fixation processes. The air losses associated with this type of process are usually of the order of 15kg of air/kg of fabric. In theory, exhaust rates of only 10kg of air/kg of fabric should be adequate and savings of 30 to 40% in energy should be possible in some cases. However, a number of processes such as the pre-setting of synthetics can cause so much fume that there is no option but to operate at maximum airflow. The opportunities for saving energy are shown in Figure 3.

- Minimise air losses
- Control fabric dwell times
- Alternative systems
- Conversion to direct gas firing

Figure 3: Opportunities for saving energy – Heat Setting

Infrared pyrometers can be used to control the dwell time in the stenter and eliminate traditional but wasteful safety margins. The installation of pyrometers at a capital cost of £34,000 gave a payback of 18 weeks with most of the savings being made from increased production rates. If energy alone was considered the payback was in excess of two years.

As an alternative method infrared panels have found application for the curing of some fabrics and research has shown that they could be used more extensively to improve the energy efficiency of heat setting and dye fixation processes. An experimental unit installed to dry wool and cashmere products has proved to be extremely efficient in increased production and reduced energy requirements without compromising the quality of the product.

Conversion to direct gas firing was considered as part of a project for the introduction of point of use heating to a print steamer. The new unit was fitted with a steam generator and gas fired liquid phase heater making it independent of the main boiler house. The old steamer was compared with the new system and overall savings of £139,000 per year were made on a investment of £380,000. This represented a payback of 2.7 years.

To comply with legislative requirements and at the same time recover some of the energy associated with the exhaust air the use of heat exchangers and exhaust filtration units should be considered. For the fitting of heat exchangers and exhaust filtration to four stenters used for the heat setting of a range of fabrics from man-made fibres a project capital cost of £120,000 was envisaged. The heat recovered from the exhaust gases was used to heat water for the dyehouse. This produced savings of £56,000 per year. However, there were annual running costs such as new replacement filters and increased electricity usage of about £15,000 leaving a net saving of £41,000. For the initial outlay the payback on energy alone was three years.

PLANT SERVICES

When looking at energy and water savings it is difficult to detach the plant services from the processing. Three significant areas need to be considered i.e., the steam raising plant and distribution systems; the electricity supply for motive power, compressed air and lighting; as well as water storage, distribution and use. In a typical dyeing and finishing company the process energy requirements are normally met from steam from a central boiler for water heating, contact heating and space heating; direct gas firing of stenters, bakers, infrared panels, coating machines etc.; and electricity providing lighting, motive power and powering compressed air systems

Energy savings for boilers

Boiler distribution losses are typically 20 to 30% of the gross fuel input. It is, therefore imperative that such losses are minimised by automatic or at least regular manual, flue gas composition and temperature monitoring. The most obvious opportunities to save on energy are not always practised and these include such simple measures as insulation of pipework and the return of condensate. Flue gas heat recovery is suitable for gas fired boilers but could only be considered if the condensate return is unavoidably low or there is a need for a continuous supply of hot water.

Energy savings for electrical systems

Electricity may only be 5 to 10% of the energy usage in a dyeworks, but this will invariably account for 30 to 40% of the energy cost. Even so this is one area which is usually forgotten in favour of the easier savings to be made on steam heated and gas fired machinery. The most common areas to be considered if savings are to be made include:

- Power factor - The relationship between the true and the apparent reactive power. The correct power factor can be achieved by selective use of power capacitors.
- Maximum demand – Peak rate consumption charges. Limit loads to specific times.
- Motor controllers – Low loading leads to inefficiency. Controllers match the power use to the load.
- Compressors – Air lines checked for leakage. Ratio between compressor on and off times in relation to pressure drop.
- Heat recovery – Warm air from air cooling used for space heating. Waste heat from water cooling can be passed through a heat exchanger.

- Lighting – Clean reflectors regularly and replace old tubes with high efficiency slim line tubes.

Reusing water

The use and reuse of water is an important topic in itself. With high water and effluent charges the wet processing side of the industry is always looking for ways of minimising its use. The reuse of spent liquors and rinse water is carried out at a limited number of sites where repeat shades are common place. However, this practice is difficult to introduce at most commission dyers because of the variation in the workload.

Hot water from the bleaching stage washer can be filtered and reused in the previous scouring stage. In a practical example 5000 litres of hot water per hour was saved amounting to nearly £36,000 per year savings in energy, water, and effluent costs. The payback was only five months. A second example involved the use of membrane systems. The introduction of an ultrafiltration plant enabled the processing of up to 30,000 litres per hour of wool scouring rinse water at a temperature of 50°C. Up to 98% of the water and heat is now recycled.

CONCLUSION

For energy efficient projects to be successful it is important that all staff are involved, informed, motivated and empowered. Work groups should be set up to look at improving efficiency. There should be a feedback of information on new developments and processes. Consider the introduction of reward schemes for good ideas. Action plans should be produced and responsibility allocated.

The measures that are ultimately introduced might be as simple as switching off unnecessary lighting or closing doors to prevent heat loss. Conversely, they might require complex change to working patterns. It does not necessarily follow that the most expensive measures are the best to implement. Most companies could save 5 to 10% of their energy usage with low cost or no cost measures.

What are you doing about Energy Efficiency?

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THE REQUIREMENTS FOR WASTE WATER TREATMENT IN THE TEXTILE INDUSTRY

M.J.C. Hewson

INTRODUCTION

The textile industry is still regarded as one of the largest industrial sectors, processing cotton and wool as well as synthetic fibres such as polyester, nylon, acrylic etc., and water usage constitutes a major component. The application of water is normally associated with the requirement of large quantities especially within the scouring, bleaching, dyeing and finishing sectors of the industry. Water usage has traditionally been on the basis of abstract, use and discharge with little regard for any long-term environmental impact its continued use may have. Up to 70% of water is being used in process preparation and dyeing with typical requirements for cotton being 100 to 150m^3 of water per 1000kg of fabric produced. For wool processing this figure increases to 200m^3 of water per 1000kg of fabric produced. In addition to this one needs to consider the chemical constituents of the water at discharge, the flow rate and the volume of effluent all of which can vary immensely from process to process.

NATURE OF THE PROBLEM

Before consideration is given to the potential treatment systems available the nature of the problem needs to be defined and the question asked, 'Are textiles finishing the environment?' When one takes into account the chemicals associated with desizing, scouring and washing; dyestuffs and auxiliaries from dyeing; pigments and pastes from printing; as well as the diversity of chemicals used in chemical finishing then the answer may very well be that the environmental impact is significant and something needs to be done about it.

Typical processing effluents provide a varied cocktail for subsequent treatment and will contain some or all of the following materials:

- Oils, fats and waxes inherent or added to fibres during processing.
- Vegetable or protein impurities associated with natural fibres.
- Monomers / Oligomers associated with man-made fibres.
- Residual agricultural chemicals from cotton and linen production
- Natural pigments, salts and metals.
- Processing aids e.g., sizes, spinning oils, knitting oils
- Preservatives such as PCP on imported cloth including pesticides on raw wool.
- Detergents and surface active agents from washing, bleaching and scouring
- Enzymes used for desizing but finding applications elsewhere in textiles.
- Peroxides and hypochlorites used as bleaching agents.
- Alkaline salts from dyeing operations.

However, whatever the make up of a typical effluent might be all aqueous discharges are subject to a number of standards and consents, see Table 1. Temperatures at point of discharge from machinery can be as high as 90°C and still exceed consent at discharge without some form of cooling or heat exchange. Adjustment of pH is often required. COD, BOD and suspended solids are consented to sewers but subject to limits for discharge to surface waters. Colour is already consented in some parts of the UK.

Pentachlorophenol, permethrin and cyfluthrin are restricted by legislation. Volume and flow rates form the basis for charging and are usually consented.

Table 1: Standards and consents for aqueous effluent discharge

Parameter	Standard / Consent
Temperature	Below 42°C at point of discharge
pH	Between 6 and 9 at point of discharge
BOD	30mg/l to surface waters
COD	50mg/l to surface waters
	Consented to sewer
Suspended Solids	20 mg/l to surface waters
	Consent to sewer
Colour	Below 1ppm consented
Toxic substances	Restricted by legislation
Volume and flow	Basis for charging consented

Of particular interest is the emerging colour problem and consents for discharges are based on not being able to observe any colour. However, this does present the textile industry with a problem. Given that 1ppm of colour is still perceptible by the human eye a typical padding application may still result in up to 340ppm of dyestuff in the effluent. Even an exhaust dyeing process can result in up to 60ppm of colour in the aqueous effluent. The main problem is associated with the soluble dyestuffs, which are not readily fixed to the textile substrate. For reactive dyestuffs between 20 and 50% is unfixed and for acid dyestuffs the figure is between 7 and 20%. Conventional effluent treatment systems do not always remove some of the coloured chromophores associated with these two classes of dyestuff. Colour limits for river quality objectives are now being set for certain areas within the UK.

In considering effluent treatment one must take into account the nature of the discharge in terms of its chemical, physical and biological loading, the quantities involved and the most practicable system to match both process and legislative requirements. However, which treatment process can be applied will depend on the type of pollution generated.

TREATMENT SYSTEMS

Why should we consider the need for wastewater treatment? Clearly, there are a number of reasons.

- Reduce the amount of waste to an acceptable level. The more waste that is produced leads to increased costs and increased environmental impact.
- Separation from the mixture of all potentially toxic components.
- Destruction of all toxic properties reducing ecological problems.
- Recovery of any valuable materials leading to the recycling of water and chemicals and thus reducing costs.
- Provision of acceptable materials for subsequent disposal.

However, any strategy, which results, must consider the following prioritised order the elimination of substances in processing, possible reduction in their use, potential to recycle, appropriateness for treatment, and acceptability for disposal.

If the pollution is largely inorganic in nature then it is relatively harmless. If biodegradable then it is suitable for biological treatment. If difficult to biodegrade then

Table 2: Technologies applicable to waste water treatment.

Physical	Chemical	Biological
Filtration	Neutralisation	Aerobic Digestion
Sedimentation	Oxidation	Anaerobic Digestion
Gravity Separation	Reduction	Plant Absorption
Centrifugation	Hydrolysis	Percolationg Filters
Flotation	Electrical	Bioscrubbers
Equalisation	Catalytic Oxidation	Biofiltration
Precipitation etc	Ozonolysi	
Adsorption	Ion Exchange	
Membranes		

physical and chemical systems may be the preferred option. Dyestuffs and polymers are generally difficult to biodegrade and many substances are totally unsuitable for conventional biological treatment. Invariably, therefore, a textile factory's effluent treatment system may very well be a combination of techniques because of the complex and changing nature of the effluent. The major waste treatment systems have the following characteristics they are physical, chemical, biological, thermal, solidification or combinations of these. For textiles in particular the emphasis is on physical, chemical and biological treatment systems and some of the more important technologies are highlighted in Table 2.

Significant interest is being paid to biological treatment systems especially with the design of biological filtration and scrubbing systems which have significantly reduced the amount of space required in comparison to conventional systems. However, all biological systems require continued throughput of effluent. Therefore, where the aqueous process discharge is relatively small or likely to be discontinuous then physical and or chemical treatments are more appropriate. The choice and design of water treatment is highly dependent on the nature of the waste and on the subsequent reuse or discharge of the water. It is common to have two or three stage processes incorporating chemical or enzymatic pretreatments, aerobic and or anaerobic biotreatments and final or tertiary treatments such as carbon, membrane filtration or advanced oxidation.

EXAMPLES OF WASTE WATER TREATMENTS

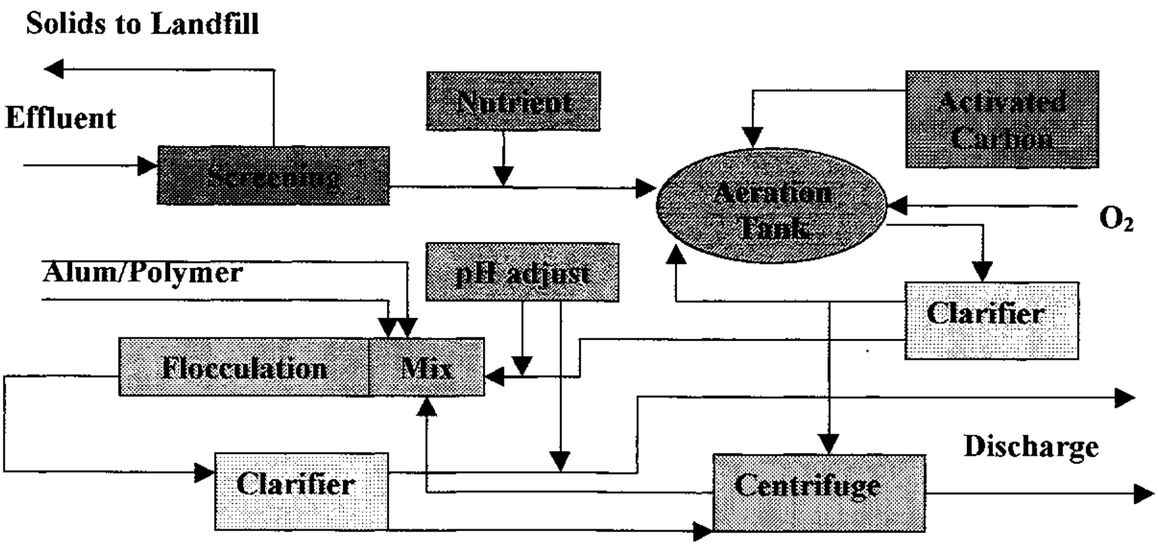

Figure 1: Activated Sludge Process for Water Treatment

The following examples highlight the techniques, which are currently available for the treatment of aqueous textile effluent taking into account the costs involved the practical considerations in meeting the choice and the rationale for choosing the methods employed. The multi-diversity of treatments required is emphasised in the Figure 1.

Effluent treatment – What options?

Originally the company set up as a wet processor during the 1800s within a rural location. The choice of location was dependent on an easy and regular source of water operating on an abstract-use-discharge basis. A river provided the best opportunity with plenty of water and an easy disposal route with no concern about the environmental impact of direct chemical discharge to the river. Popular opinions and scientific viewpoints have, however, changed significantly. Such rural locations are now popular for leisure and walking activities. There is an increased public awareness of problems with the public quick to report any unacceptable emissions or discharges. Environmental issues are important with a distinct agenda enforceable through legislation resulting in the polluter having to pay.

Performance

The organisation operates a continuous bleaching range for up to 500km per week polyester/cotton. Two dye ranges using vat, disperse and reactive dyestuffs are operated involving 150 to 200km of fabric per week. Three finishing stenters and a flame-retardant unit are also in operation. The factory operates seven days a week with some 24-hour operations. The performance requirements are driven by consumer demands for consistent cloth quality and colourfastness to light, washing, perspiration and rub fastness.

Investment Decisions

The original concept was to financially support the expansion of the local sewage treatment works with the capital investment apportioned to each participant. This would have entailed as little as £900K in 1985 but rose to £4.2M by 1990 with no control over running costs and the need for further expansion. Thus the decision was made in 1991 for an in house capital project based on previous experience with biological treatment systems.

Historically evidence suggested that a treatment system based on a biological unit would be satisfactory. However, it would require better balancing and a more consistent flow with the ability to be able to expand if necessary. The loading would be increased from $1000m^3$ to $1500m^3$ per day treating up to 3500kg of BOD per day instead of only 800kg.

Objectives

- Designed to run with the minimal of intervention.
- Colour removal achieved using Dissolved Air Flotation (DAF).
- Final polishing of discharge water with sand filter.
- Changes in future BOD limits considered.
- Allow operations to continue in the event of break down.
- Does not pollute the local river and meets consents for discharge to sewer

Results of Exercise

- Colour removal established.
- Waste sludge filter pressed and deposited to land.
- Recycling of water via lodge of a quality for reuse.
- Discharge of water meeting EA requirements.
- Capacity to continue processing if problems arise with treatment systems.

Lessons learnt from exercise

- Cannot forecast the actions of authorities in changing and enforcing legislation.
- Cannot forecast changes in fashion which dictate the processing requirements
- Always carry out pilot scale studies on the worst possible scenario.
- Effluent treatment is an integral part of process management.
- Understanding the variables requires time and they continue to vary.
- Do not underestimate the time required to establish the optimum conditions.
- With your own in-house plant you have better control of your own destiny.
- You never stop learning.

Schematic layout

Figure 2 illustrates the techniques employed to treat the aqueous effluent. Whilst aerobic digestion was the main treatment for bulk effluent, segregation of effluent streams allowed the printing effluent to be treated chemically followed by separation using dissolved air flotation and subsequent recycling of water

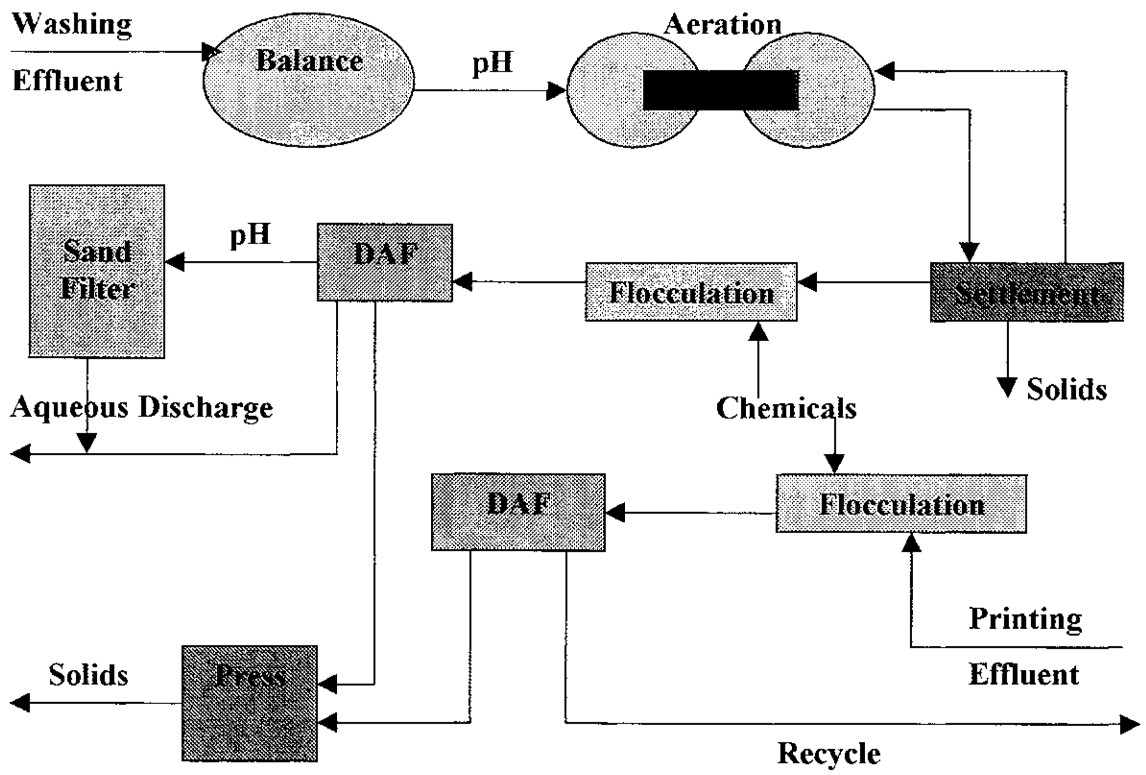

Figure 2: Commercial Effluent Treatment System - Rural Area

Tourism and Industry Side by Side

A textile company based in the south west of the UK on the banks of a Class 1A river. Largely concerned with dyeing and finishing of 300km of fabric a week, using reactive dyestuffs and discharging direct to the river. Major requirement for the treatment of 3600m ^{3} of water per day with the principle problem of colour removal. In this case significant restriction on space ruled out the conventional biological treatment systems.

Consideration was given in this case to energy recovery before treatment commenced and a suitable heat exchanger was installed before the initial holding/balancing tank. Treatment comprised of an initial coarse filter followed by chemical dosing with lime, ferrous sulphate and a polyelectrolyte. Separation occurred in a settlement tank with the sludge being dewatered and disposed to landfill. The water was pH adjusted using carbon dioxide rather than conventional mineral acid dosing and discharged to river. The introduction of a biofiltration system has improved the quality of the discharged water further reducing the BOD levels.

The running costs are of the order £4500 per week for chemicals adding approximately 5p cost per metre of fabric dyed and finished. A schematic layout of the treatment system is shown in Figure 3.

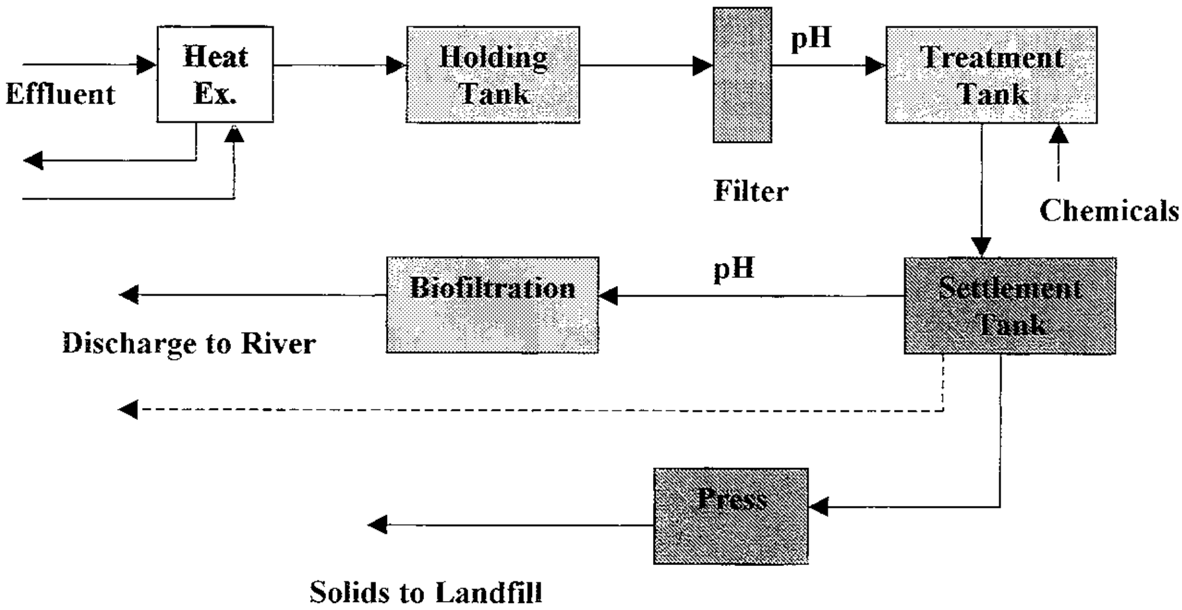

Figure 3: Commercial Effluent Treatment System – Tourist Area

Aerobic vs Anaerobic Digestion

Conventional biological treatment systems have concentrated on the activated sludge approach to reducing BOD and COD within textile trade effluent. In aerobic treatment processes liquid wastes are fed into a reactor containing a microbial population. Air is supplied to provide oxygen to enable the microbes to respire, metabolise the organic molecules and grow. Various reactor configurations are used which aim at maintaining a high concentration of microbes to maximise digestion rate. Options include using immobilised microbes as trickling filter beds or recycling a portion of the microbes produced as in activated sludge processes. Wastes are metabolised to carbon dioxide, water and biomass. The biomass is removed from the water as sludge. Some non-metabolised components can be accumulated in the sludge by adsorption. A liquid discharge of low BOD (10mg/l) can be produced. Enhanced performance can also be achieved by the injection of oxygen.

However different microbial populations exist in anaerobic digestion systems in which air is excluded since these micro-organisms are sensitive to oxygen. The organics present in the effluent are metabolised to yield biomass plus a gaseous mixture containing methane and carbon dioxide. The gas can be used to power a generator providing energy as a useful by-product. The process achieves a large reduction in BOD of high strength wastes and has the advantage of producing relatively low amounts of sludge. It does not however, reduce BOD to the low levels achieved by aerobic digestion. Thus anaerobic digestion for liquid waste treatment tends to be restricted to situations where energy recovery is attractive and or where the discharge effluent is not subject to strict BOD limits. Alternatively, anaerobic digestion might be used as an efficient pre-treatment for very high BOD waste prior to aerobic treatment.

Anaerobic digestion has been investigated for the treatment of wool scouring effluent. Initial results were found to be promising with pesticide removal greater than 80% and COD/BOD removal between 70 and 90%. Nutrient requirements were minimal and process optimised to run at pH 6.5. However, the overall performance was disappointing and steady state conditions were difficult to achieve. A schematic layout of a treatment system is shown in Figure 4.

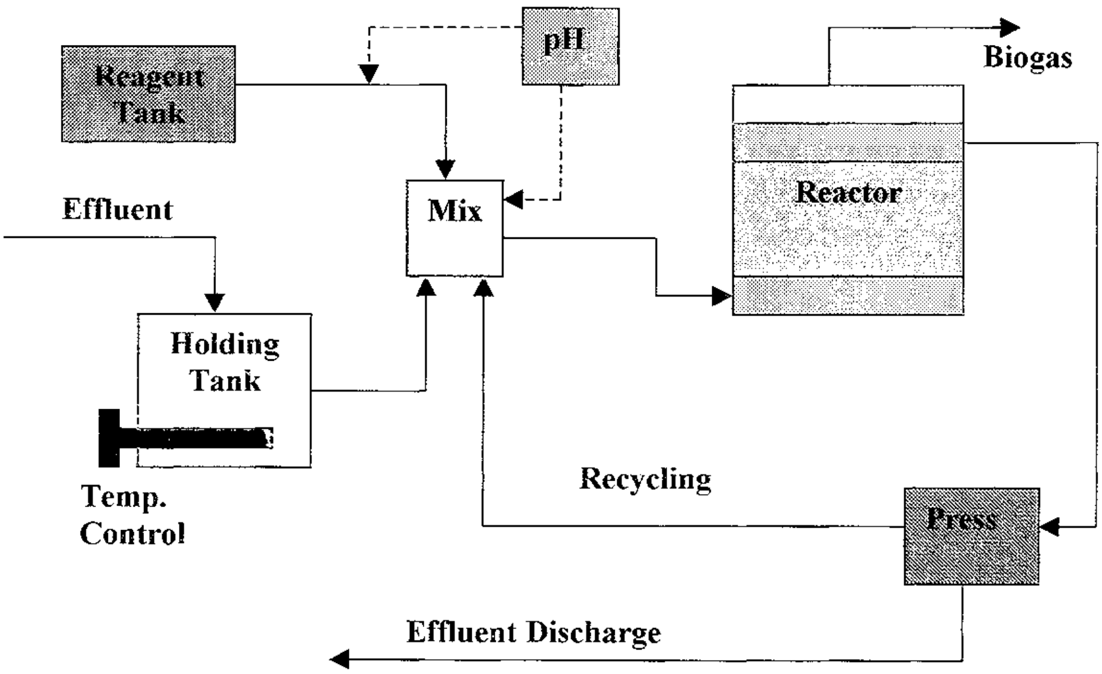

Figure 4: Anaerobic Digestion of Wool Scouring Effluent

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INITIAL RESULTS FROM AN EU-FUNDED RESEARCH REED BED

Patrick Gaunt

INTRODUCTION

The background to this project was a growing awareness of an impending crisis in the Textile Industry around Bradford. Wool Textiles, although a shadow of its former self, is still one of the most important employers in the Bradford area and "Made in Yorkshire" still commands respect throughout the World. However two new and significant factors were posing a threat to manufacturers in the region: 1.the cost of effluent processing and tightening legislation 2. the cost of a reliable water supply.

The project is investigating the feasibility of effluent filtration and biodegradation to allow 100% re-use of the water. The process utilizes bacteria growing in the soil and around the root systems of the common reed. Similar systems have been used with great success in other areas such as ICI and British Steel in the UK and Wendel Textil GmbH in Germany. However much more experimental data is required - especially on the removal of insecticides - before they will be taken up wholesale by the relatively conservative local wool textile industry. There is specific work being done to investigate whether adequate purification can take place through relatively small plots as the layout of most local mills does not allow large areas to be turned over to reed beds. Process alterations are being investigated to reduce water usage and increase effluent concentrations.

THE NEED FOR THE PROJECT

Environmental

The days of running effluent into water courses and paying the Environment Agency a discharge fee are numbered. Most companies realise that, quite apart from the morality, the potential legal penalties are severe and the costs are enormous (even where the effluent is quite clean the cost reflects the potential contaminants). Apart from this the Environment Agency are tightening up on what they will allow to be discharged at ***any*** cost. Of course these discharge considerations feed back through the normal foul sewer disposal of effluent because Yorkshire Water is constrained by the Environment Agency as to what it can discharge to rivers. Over the last five years we have seen a severe tightening of standards and this process is set to accelerate as the UK is brought in line with Europe at the same time as Europe cleans its act up.

There has been a shift of emphasis by Yorkshire Water over the last few years. They now perceive their main customer to be the domestic consumer and they have lost any feeling of responsibility for supporting employers in their region. The good supply of water built up over the last century for the textile industry has proved inadequate for the massive increases in domestic water consumption. Although Yorkshire Water is, belatedly, taking steps to safeguard supplies long-term climatic changes and the environmental objections to reservoir construction will make water conservation a prime objective for responsible manufacturers.

There is also a strong case for the treatment of industrial effluent at source. Companies like Yorkshire Water must design their treatment plants for the optimum processing of domestic effluent. This would be compromised if they attempted to remove all the contaminants entering the sewer from commercial enterprises. Reed beds, because they are dynamic system of live organisms, are adaptive and quickly become specific at treating the effluent fed to them. (one to three weeks[5])

Cost

Both effluent disposal costs and water provision costs are rising at rates well above inflation and will have become a significant proportion of direct costs. The viability of many employers in the area is being marginalised. However reed bed based effluent processing offers the potential for recycling of water at very low running cost.

A SHORT HISTORY OF REED BEDS

Professor Kickuth and the Root Zone Method

Professor Kickuth can fairly claim to be the father of Reed Bed Technology and his original design (over which he had various intellectual property rights) forms the basis of many reed beds in existence today. Water flows horizontally through soil in which are growing lymnophytes (wetland plants). The water level is maintained below the surface of the soil and soil depth is generally between 0.3m and 0.7m. There is a distribution and collection manifold and the whole unit is isolated by an impervious barrier.

This was first implemented in 1974 at Othfresen in Germany to treat domestic sewage on a site formally used for dumping waste from the mining of iron ore. His design was partly developed from observations of natural reedbeds' capacity to remove pollution and partly as a means to increase the capacity of land to process sewage. The capacity of grassland to treat sewage run onto its surface has been used for many years by conventional treatment works but the addition of wetland plants increases the capacity greatly[1].

The role of the plants is to create a hydraulic pathway which, because it is a living organism, is self maintaining. Wetland plants (ie bulrush - *Scripus validus*, common reed - *Phragmites australis* and cattail - *Typha latifola*) also transport oxygen into the

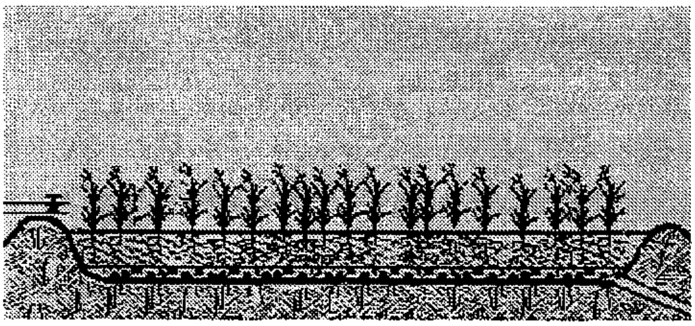

Figure 1: Typical root zone bed

volume around their rhizomes (rhizosphere) at rates between 5 and 50$gm^{-2}day^{-1}$ [2]. (Rates of oxygen flux have been measured at around $2x10^{-5}$ mg m-$root^{-1}s^{-1}$ depending on time of day and other factors.)[3]

The distinguishing feature of the Root Zone Method is the use of soil as the reed bed medium. This provides a large surface area for bacteria to digest the effluent - although the concentration of bacteria in the rhizosphere is a hundred times greater than in the top soil, the overall volume of soil is much larger. (ie 10^{16} m^{-3} compared with 10^{14} m^{-3})[2]. Soil also allows greater potential for adsorption and the creation of complexes of phosphorous and other metals.

The main criticism of soil is its low permeability. Professor Kickuth claims a hydraulic conductivity of 10^{-3} to 10^{-4} ms^{-1} in the top 0.3m of soil with high concentrations of rhizomes (the A horizon) falling to 10^{-7} ms^{-1} below this. However many people attempting to emulate Kickuth's work failed to achieve the values reported by him and substituted sand or gravel for soil.

Alternative designs

Gravel or Sand systems

These have become widely used in certain areas and probably appeal to engineers from the traditional waste water treatment industry. In general, the hydraulic behaviour of sand or gravel systems is more predictable and can be calculated in a less empirical way. However, because the hydraulic conductivity is not as closely related to the presence of the rhizomes there is a likelihood of effluent passing underneath the active volume of the bed.

Vertical flow systems

In a vertical flow system the effluent is run over the surface of the bed and allowed to seep downwards. The bed has a gravel bottom to allow efficient drainage (if the

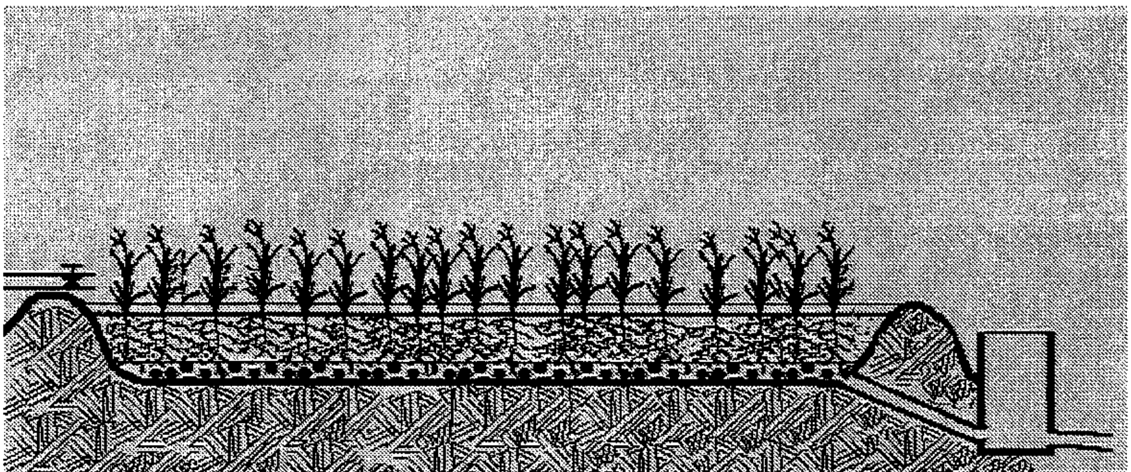

Figure 2: Vertical Flow Bed

growing medium is gravel then the bottom layer must be of larger particle size to give greater hydraulic conductivity). The vertical flow systems have relatively short flow lengths which reduces their ability to remove certain pollutants but they can treat high ammonia loads efficiently (such as in the British Steel plant mentioned earlier[4]).

Free water systems

Free water reed beds are artificial swamps where the wetland plants are either floating on the effluent or growing up from a solid substrate which is completely submerged. Free water systems have their advocates and they are often more "natural" in execution, however they invariably require a greater land area for an equivalent reduction of COD. In addition free water systems are prone to problems such as smell and mosquitos.

REED BED DESIGN AND PERFORMANCE

COD reduction

Chemical oxygen demand (COD) or Biological oxygen demand (BOD) are commonly used as a measure of the strength of effluent. They indicate the quantity of oxygen which in needed to oxidise the reactive components of the effluent.

From the rate of transfer of oxygen by the wetland plants (above) a limit can be calculated for the rate of reduction of oxygen demand of between 5 and 50$gm^{-2}day^{-1}$ ie

$$Q\,(C_0 - C_t) / A < 5 \text{ to } 50 \text{ g m}^{-2} \text{ day}^{-1}$$

where A is the surface area of the reed bed in m^2, Q is the volume flow rate in m^3day^{-1} and C_0 and C_t are initial and final oxygen demands in mgl^{-1}. However the actual rate of COD reduction is very much lower than this limit.

In actual fact the phenomenon occurs as an oxidation process in association with aerobic bacteria in the soil adjacent to the rhizosphere. The rate of removal behaves approximately as first order reaction (where the rate is proportional to the concentration) this can be written:

$$C_t = C_0^{-kt}$$

where C_t is the concentration after time t, C_0 is the original concentration and k is the reaction coefficient. With negligible leakage or evaporation the time variable t is proportional to distance across the reed bed. It can be seen that the concentration falls exponentially which means that smaller volumes of high concentration can generally be treated using a smaller bed than for large volumes of weak effluent.

The reaction coefficient depends on a host of factors but fundamentally the temperature (Arrhenius' law states that the reaction rate approximately doubles with a 10^0C increase in temperature), transpiration rate of the reeds, treatability of the effluent and quantity and type of bacteria. From the above equation it is possible to derive the following relationship:

$$A = f\,Q\,(\ln C_0 - \ln C_t)$$

where f is an empirical factor; 5.2 is often used for BOD removal from domestic sewage using a bed 0.6m deep. For treatment of industrial effluent the factor may be more than three times this figure[2]. The factor takes into account the much reduced capacity of the reed bed during the winter months.

The area available for a reed bed at RG&S was $625m^2$ and using a value for f of 10.0, the following table can be derived for the maximum capacity of the bed:

Influent COD mgl^{-1}	**Effluent COD** mgl^{-1}	**Volume** m^3day^{-1}
300	50	35
500	50	27
700	50	24
900	50	22

A major objective of the project is to determine a reasonable value of f for the effluent of the local wool worsted textile industry, the soil type used and the climatic conditions.

Hydraulic conductivity

The hydraulic conductivity and slope govern the configuration of the reed bed:

$$A_c = Q/(k_s\ S)$$

where A_c is the cross-sectional area Q is the flow rate k_s is the hydraulic conductivity and S is the slope. The slope can be greater than the slope of the bottom of the bed by creating an inclined water table. For the reed bed at RG&S: if Q of 24 m^3day^{-1} is used, cross-sectional area of $35m^2$ and k_s of $2x10^{-4}ms^{-1}$ the result is a slope of 0.04. As the slope of the bed is 0.02, then there has to be a gradient of the water table of approximately 0.04-0.02 = 0.02 and the working depth needs to be reduced accordingly (at RG&S the length of the bed is 10m, so the depth reduction down the bed in the above example would be 0.2m).

As mentioned above experiences have varied from $10^{-3}ms^{-1}$ to $10^{-6}ms^{-1}$ but in practice hydraulic conductivities in excess of $5x10^{-4}ms^{-1}$ have regularly been measured for soil based reed beds which have been in operation for more than five years [4].

Hydraulic retention time

The determination of the surface area of the bed for a given flow rate and depth "fixes" the hydraulic retention time of the effluent. However it is still a useful parameter in the design of the reed bed and can be measured relatively easily in order to check the hydraulic performance. Many people require minimum retention times of six or seven days.

For the example worked through above: volume flow is $24m^3day^{-1}$, depth is 0.6m falling to 0.4m giving a volume of the bed $312m^3$. The hydraulic retention is 13 days. However the working depth of the bed is often limited when processing industrial effluents which reduce the growth of the root structure. To give a minimum retention time of 6 days the bed must operate with an average working depth of about 0.25m

Bed depth length and width

All of the above calculations lead to limits on the dimensions of the reed bed but these depend critically on the hydraulic conductivity profile and the effective depth of the bed.

For the RG&S reed bed using the examples above the depth varies from 0.6m at inlet to 0.4m at outlet giving an average of 0.5m, the width 70m and the length 10m. However, if a value of hydraulic conductivity of $4.0x10^{-4}ms^{-1}$ is used instead of $2.0x10^{-4}ms^{-1}$ then the dimensions change to a width of 35m and a length of 20m. The design is usually fairly empirical and is based on the experiences of the reed bed experts involved.

Removal of other contaminants

Suspended solids

These are removed very efficiently by soil type reed beds. Because the system, once established, is in dynamic equilibrium the filter does not clog up. For sludge dewatering vertical mode reed beds are often used.

Nitrogen

Unlike conventional sewage plants reed beds have areas of aerobic bacterial activity which nitrify effluent as well as areas of anaerobic and anoxic soil where denitrification occurs. This is important in the removal of nitrogen from domestic sewage as it generally exists as both Ammonia and as Nitrates or Nitrites. The rate of ammonia nitrogen removal during the winter months could be the limiting factor in designing reed beds for certain applications. (However specific problems can be designed around as in the case of the British Steel plant where a vertical flow bed was used specifically to reduce high ammonia levels).

Phosphorus

This can be removed effectively provided the right type of soil is used. Negligible phosphorus is absorbed by the plants, the mechanism of removal is being by the formation of complexes with iron or aluminium in the soil. Phosphorus adsorption is sometimes seen as the limiting factor on the life of the reed bed but, with the correct soil type, at the stage where phosphorus can no longer be absorbed by the system the concentrations will probably have reached commercial ore grade! [2]

Sulphur

This is removed by reduction of sulphates to sulphides and oxidation of sulphides to elemental sulphur and sulphur esters which are precipitated in the soil.[5]

Metals

Most toxic metals are absorbed in the reed bed - slowly building up concentration in the soil. Chromium at concentrations above $10mgl^{-1}$ causes dwarfing of Phragmites but can be tolerated up to 4000mg per kg of soil. Copper and zinc at high concentrations ($10mgl^{-1}$) can be taken up into the reeds where their is a chance of them entering natural food cycles.[2]

Organic chemicals

Most are oxidised effectively by aerobic bacteria in the reed beds, at ICI Billingham the design objective was 90% removal and this has been achieved and comfortably exceeded in certain instances [4]. However, some chemicals are toxic to the reeds and have to be diluted accordingly for example herbicides, xylene, toluene and alkalated benzene substnaces.[2] One of the objectives of the project is to assess the efficiency of the reed bed at removing the organo-phosphorus and organo-chlorine compounds used as insecticides (in sheep dip and moth-proofing).

Suitability for textile effluent

One of the early examples of using reed beds for the treatment of industrial effluent was as Windel Textil GmbH & Co in Germany. In 1974 Professor Kickuth built a treatment plant utilising variations of his Root Zone Method. The factory is mainly involved with dyeing and bleaching cotton and synthetics. The effluent has a COD of 1500mgl-1 and contains up to 400 compounds mainly chromium, copper, antimony and sulphur compounds from dyeing and silicates from bleaching, the overall pH is 10 to 11.

The volume of effluent is $3000m^3day^{-1}$ and is treated using 27 hectares of reed beds. It achieves a winter average of $135mgl^{-1}$ COD at the outflow which is discharged into the river Lutter.[4] The colour removal is also within consent limits. The retention time is quite large as certain contaminants are hard to biodegrade, also the strength of the effluent has limited the growth of the rhizomes to the top 0.25m in certain beds. In some beds a soil depth of 0.3m was used during the construction but this caused problems of freezing during extreme cold spells.

The reed bed at Wendel worked well but it required a large amount of land (more than had originally been envisaged). The efficiency of removal of insecticides as found in the Yorkshire wool worsted industry needs further investigation.

THE CONSTRUCTION AT RG&S

The design considerations

The finishing plant at RG&S contains only cloth scouring with no dyeing or bleaching. The 7500kg of fabric processed each week contain small amounts of loose dye, emulsifiable lubricants and waxes and, occasionally, traces of sheep dip chemicals which have not been removed by previous scouring operations. Auxiliaries used in scouring include detergents, silicone softeners and specialist stain removal additives (some containing chlorinated hydrocarbons).

An important function of scouring is the development of the fabric "handle" and much of the time and water used is not primarily for cleaning the fabric. In the past this has not been a serious problem as the mill has its own bore-hole and abstraction and effluent charges have been low.

The average water consumption was $55m^3day^{-1}$ over the year, averaging $73m^3day^{-1}$ during busier spells with maximum daily usage around $125m^3$. Thus the overall liquor ratio for the scouring operation was approximately 1:50

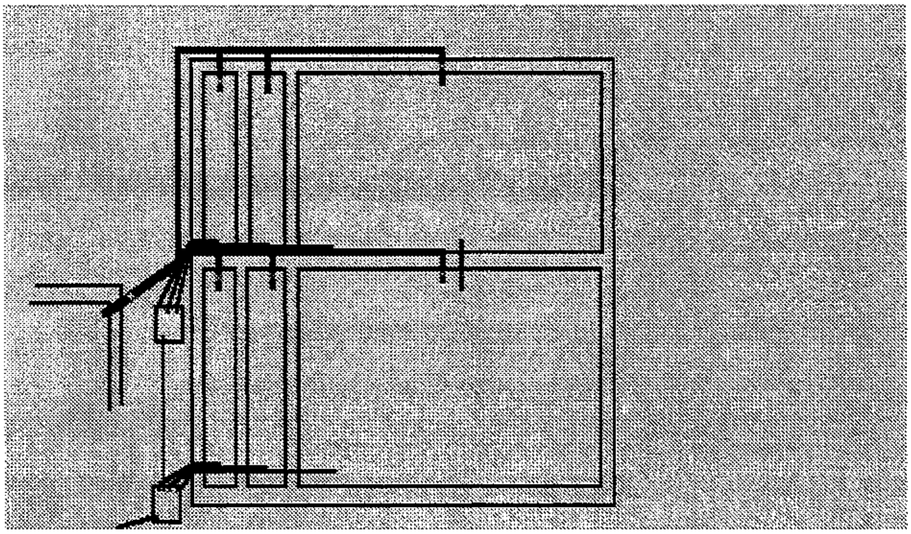

Figure 3: The layout at Reuben Gaunt & Sons

The effluent strength has been correspondingly low: average COD 328, settleable solids of 38 and pH 7.5. An important objective of the project has been to reduce the volume of water used to20 to $30m^3day^{-1}$ and so increase the effluent strength to 640 to $940mgl^{-1}$ COD.

The reed bed specialists involved in the project are Oceans Environmental and the building contractors were Keenstead - a local firm. To accommodate the potential variation in the feed effluent and to allow the maximum degree of experimentation the layout chosen was two larger beds which could be run in parallel or series and four small beds to be used as trial beds for participants from other companies.

The retaining "bund" and internal dividers were constructed from dry layed concrete blocks to reduce the wasted area (compared with compacted earthworks). The beds were lined with HDPE 1mm thick. The underside of the reed bed had a slope of 0.02 and the top surface was level over half its length and sloped over the lower half by 200mm.

Costs

The costs for the construction at RG&S have been high; a reasonable quantity of top soil had to be bought in, various features were incorporated to allow trials to be performed, block work dividers were used and a waterproof liner had to be used because the subsoil was not impermeable. For these reasons the construction costs were around £$50m^{-2}$. However a figure of £$15m^{-2}$ is more in line with costs achieved on larger systems and is quite feasable with the knowledge gained during this project.

In 75% of the reed beds installed by Professor Kickuth the top-soil existing at the site has proved adequate with no modification.[2]

Operating costs are very low: weeding during the first season or two and testing of effluent quality. For the effluent stream from RG&S with no re-use of effluent the target criteria are:

	Prior to project	Process mod^{ns}	After reed bed
Volume, $m^3 day^{-1}$	55	24	24
COD, mg l^{-1}	328	800	80
Solids, mg l^{-1}	38	100	5
Treatment charge, £ m^{-3}	0.36	0.48	0.30
Cost p.a., £	7200	4200	2600

So even with the effluent from the reed bed discharged to sewer there is a saving (although probably only justifying £7000 of the reed bed capital cost). However if the effluent can be re-used or the reed bed removes certain "banned" substances completely then the cost implications become very significant.

Unforseen problems

The site at RG&S turned out to quite boggy due to a small spring. This caused two problems, firstly the earth moving machinery proved unsuitable and rather than"blading" the site, the earth had to scooped into a dumper truck. The foundations of the block work walls were also difficult to consolidate and required bedding with gravel. Secondly, the weeds which were contained in the top-soil (some of which was blended and used in the reed bed) were not killed by flooding the beds. This is normal practice for weed control but in this case manual weeding was required.

The mother-in-law of the chief weeder won the lottery half way through the job and his devotion to environmental causes came a poor second. This delayed the project by a few weeks.

Timing

Although the reeds were planted at RG&S in May the optimum time is in October. This would have enabled more meaningful results to be obtained during summer 1997.

INITIAL RESULTS

Influent volume reduction through process modifications

The scouring method at RG&S has remained unaltered for many years. It is a batch operation scouring six pieces or about 150kg of cloth. The most common routine was:

15min scour (using c. 0.9m^3 water and 2kg detergent)
15min overflow rinse (using c.2.2m^3 water)
15min scour (using c. 0.9m^3 water and 2kg detergent)
40min overflow rinse (using c. 6.0m^3 water)

with a total water volume of 10m^3. Following analysis of the COD values of the scouring and rinse water the routine was revised to use batch rinsing with four lots of 0.9m^3 water being used for rinsing giving a total water consumption of 5.4m^3 per batch.

The main concerns are dye or dirt re-deposition during scouring, tangling or dragging causing damages to the cloth and poorer lubrication of the fabric causing running marks. The operatives are conservative and the process is moving in stages, however it is hoped to reduce the water volumes further.

Flow rates through the beds

Accurate measurements have not been made of the flow rates through the beds but the indications have been that suspended solids have been clogging the surface of the gravel distribution manifold. This has caused partial surface flow over the bed. The proposed solution is to form mesh lined holes to the bottom of the gravel, these will require the felt of suspended fibres to be removed as they build up (once per week perhaps).

Apart from the above observation the flow rates observed have been of the order expected from the design ie c. $12m^3day^{-1}$ through each half of the bed.

COD removal

Measurements, shown in Table 1 and taken during the first winter after the reeds had been planted showed a significant COD reduction although this was not at flow rates or from COD levels expected to prevail after the process modifications have taken effect. The COD removal is nowhere near the target performance of 640-940 mg l^{-1} at present. NH_4 and chromium removal has been good.

Sample ref	pH	COD	TDS	NH_4	SO_4	Cr
Borehole water	8.7	<15	0.78	<1.0	<500	<0.5
Prior to detergent	8.6	30	0.76	<1.0	<500	<0.5
1st scour	7.9	5250	0.8	11.3	<500	<0.5
2nd scour	8.2	1350	0.78	5	<500	<0.5
2nd rinse	6	1239	0.82	6.3	<500	<0.5
Final effluent	6	1585	0.88	10.8	<500	<0.5
Reed Bed 3 inlet	7.6	212	0.76	6.5	<500	<0.5
Reed Bed 3 outlet	7.3	161	0.72	<1.0	<500	<0.5
Reed Bed 6 inlet	7.5	251	0.74	6.4	<500	<0.5
Reed Bed 6 outlet	7	177	0.7	1.1	<500	<0.5
1st scour sample 1	7.4	1298	0.84	10.8	<500	0.9
1st scour sample 2	7.4	1374	0.84	11.75	<500	0.93

Note: TDS = Total dissolved solids

Table 1: Effluent analyses during the winter after reed planting

SUMMARY

The effluent being produced by Reuben Gaunt & Sons Ltd. (RG&S) was analysed and an appraisal made of possible future contaminants, the effluent was also compared with data from other textile companies and other industries. A reed bed was designed and built on the available land using soil as the growing medium and a horizontal flow configuration. Effluent has passed through this since June 1997 and it will continue on an experimental basis for three to five years (although the useful life of the beds should be over twenty years). Over the first two years of the project the condition of the beds, the flow rates and the quality of the outflow are being closely monitored to determine the performance of the system. Other companies in the textile industry and leather industry have been involved and specific experiments will be done to assess the possible suitability of the technology to other companies. A best practice booklet will be written and made available to the textile industry on completion of the project.

CONCLUSION

The use of reed beds for the treatment of wool textile effluent shows promise although hard evidence will not be available for a year or two. In many diverse industries reed beds have already been proved to be effective but in some instances the land area required is large. There is no reason to doubt that they will prove capable in this industry also but the question of whether adequate space can be found at the existing, generally urban, sites remains to be answered.

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MINIMISATION OF FORMALDEHYDE EMISSIONS.

Michael Hall, Richard Horrocks and Dawn Roberts

INTRODUCTION

During the application of durable chemical flame retardant, Pyrovatex* to cotton fabric, the treated fabric is heated to ensure permanence of the chemical treatment[1]. This causes a reaction between the chemical and the cotton which releases formaldehyde into the treatment oven. This is normally vented to the atmosphere via a high chimney or stack. However, all such emissions must comply with the Environmental Protection Act 1990 and hence formaldehyde emissions must not exceed the limits specified in the Secretary of State's guidance note PGG6/8, which limits formaldehyde emissions to the atmosphere to 20ppm. A research programme was started at Bolton with funding from the then UK Department of the Environment (now the Department of Environment, Transport and the Regions) under the Environmental Technology Innovation Scheme (ETIS) to try to reduce the emissions of formaldehyde during the application of this particular flame retardant.

The current legislation on the emission of formaldehyde from stack gases is 20ppm. However, since this figure is considered to be on the high side, it was decided at the start of this project that the main aim of the project should be to reduce this by 75% to meet any future changes in legislation and so this was the target which was set at the outset. One important point was that whatever changes were made to flame retardant formulations or processes, the final product properties must be maintained. A secondary aim was to reduce the level of phosphorus in the liquid effluent, which is normally discharged to sewer.

PYROVATEX CHEMISTRY

Pyrovatex is a reactive flame retardant, which will react with cotton under the appropriate conditions to give a durable flame retardant finish, which will comply with the legislation for upholstery fabrics, curtains and children's nightwear. The flame retardant is applied to the cotton fabric in combination with a melamine resin, a fabric softener and phosphoric acid that acts as a catalyst. The Pyrovatex bonds directly to the fabric with the melamine resin acting as a bridge. Thus a typical formulation for applying to a fabric at a nominal 100% expression would be:

	%(w/v)
Pyrovatex	28
Melamine resin	3.5
Softener	2.5
Phosphoric acid	2.0
Wetting agent	0.125

Note: *Pyrovatex CP is N-methylol dimethoxyphosphonoproprionamide and is a registered trademark of Ciba Speciality chemicals

The chemistry of this process is indicated in Figure 1:

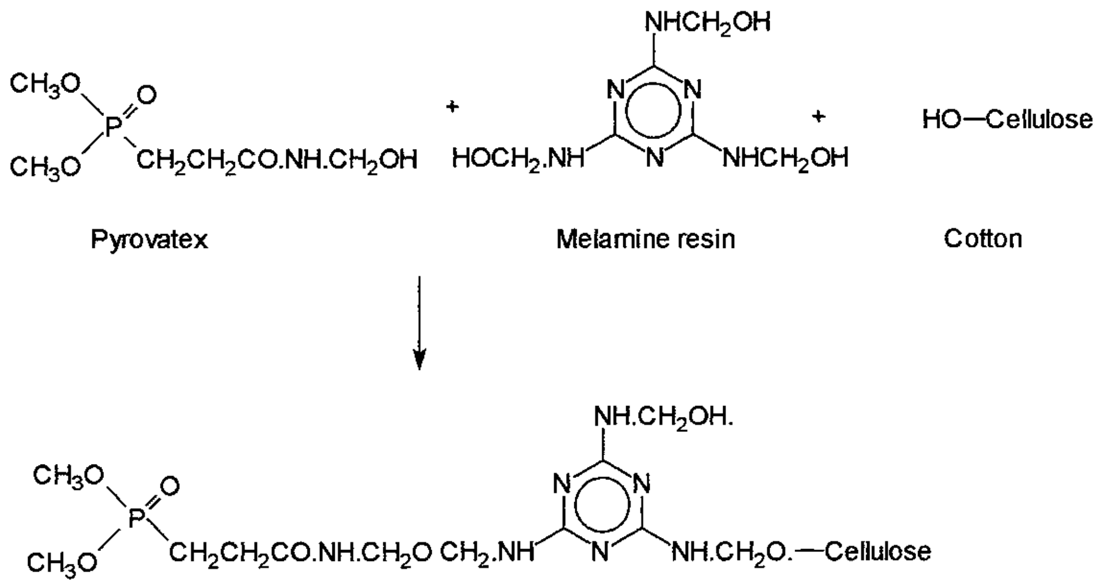

Figure 1. The Chemistry of the Pyrovatex Process

The reaction onto the cellulose hydroxyl groups is via the methylol group with the elimination of water, leading to the ether link to the cellulose molecule. Side reactions do occur, for example the methylol group can react with itself with the evolution of formaldehyde as shown in figure 2.

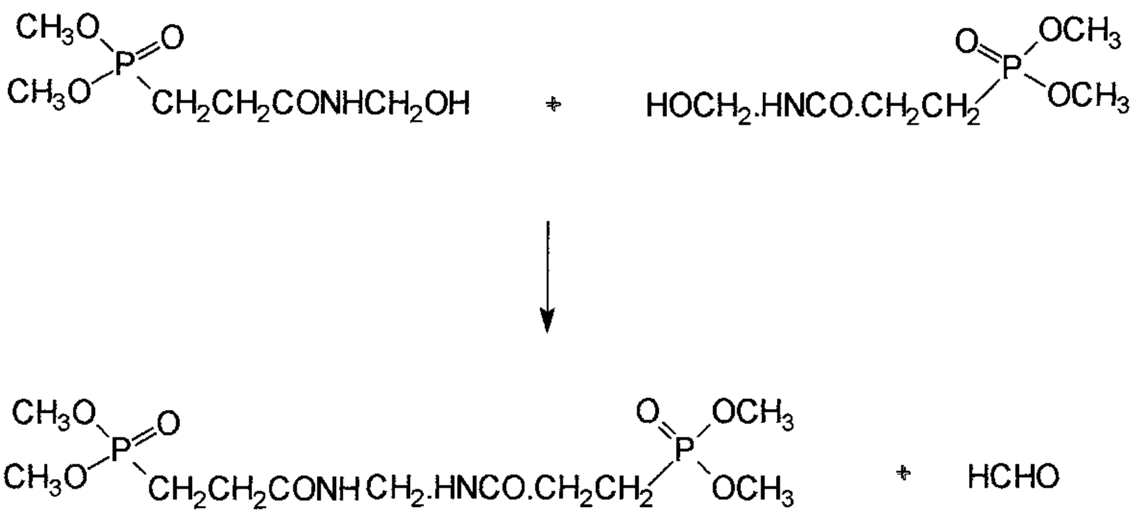

Figure 2. The Formation of Formaldehyde

Commercial Application of Pyrovatex

Pyrovatex is applied commercially via the pad- dry- bake technique. This is shown diagrammatically in Figure 3.

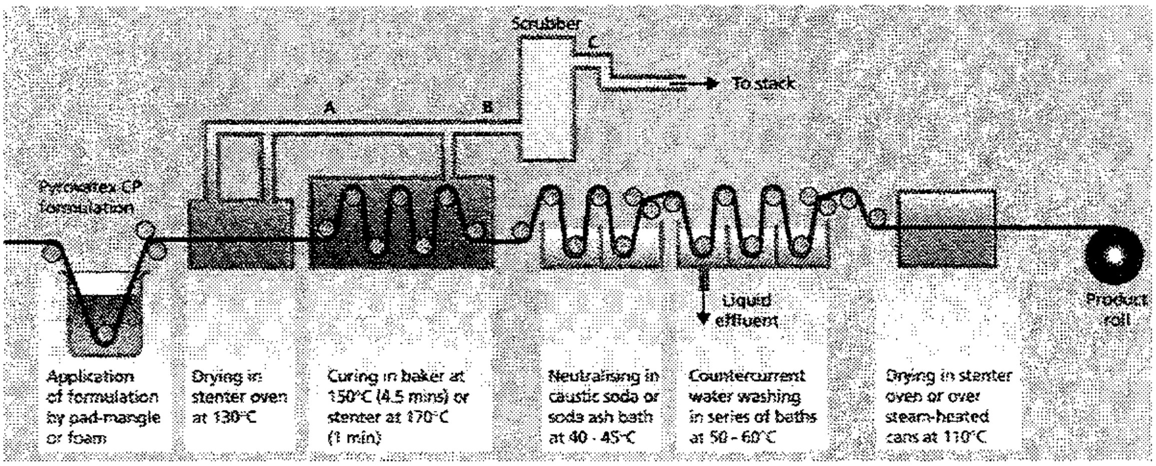

Figure 3: The commercial application of Pyrovatex flame retardant[3]

The various sampling points are also illustrated to indicate where formaldehyde analysis was performed during the plant trials. While the pad mangle technique is still used in the application of pyrovatex, it is now more common to see minimum add on techniques such as foam application being used because this leads to a softer final product with improved durability.

ANALYTICAL TECHNIQUES

At the start of this project it was decided to investigate the various methods available for the analysis of formaldehyde. These ranged from the simple Draeger tubes to gas chromatography followed by mass spectrometery. The problems encountered by each of these techniques are elaborated below.

Draeger Tubes:

These are simple to operate but only suitable for one off measurements and therefore not applicable to continuous measurement.

Dreschel Bottle:

This method involves bubbling the formaldehyde laden air through an entrapment solution, followed by a colorimetric estimation of formaldehyde. Again this method is unsuited to the continuous estimation of formaldehyde and has the additional disadvantage that resin particles liberate formaldehyde and hence give a high reading.

GC-MS:

The combination of gas chromatography followed by mass spectrometery is an extremely powerful analytical tool, and provides unequivocal estimations of formaldehyde, however, the equipment is not transportable and would not therefore lend itself to being moved from site to site.

VOC:

The measurement of volatile organic compounds gives a relatively simple estimation of formaldehyde provided that this is the only organic component in the discharge gases. However, our measurements showed this was not the case in the exhaust gases emitted during the cure of Pyrovatex.

FTIR:

Infrared spectrophotometry is a well established technique used in the analysis of organic compounds and Fourier Transform IR has greatly enhanced sensitivity for accurate quantitative analysis to be undertaken. The instrument is robust and was transported round four industrial sites, providing continuous accurate analysis of the formaldehyde levels at the various points of sampling. This then was the technique of choice and measurements were made by sampling the stack gases and passing these through a gas cell illustrated in Figure 4. The gases were sampled for a period of two minutes and during this time the samples were analysed some five times per second.
These analyses were then averaged

CHEMOMETRICS OR FACTORIAL EXPERIMENTAL DESIGN

The initial experiments in the research showed that formaldehyde emissions were mainly influenced by the composition of the formulations, which were applied to the fabric, and therefore the research was focussed on the recipe components and their relative and absolute concentrations.

The conventional scientific approach when studying simple reaction has been to study the effects of changing one variable at a time, whilst holding the other variables constant. Chemometrics , however, allows all the variables to be changed in a planned manner. We adopted the principles of chemometrics in our experimental design mainly to cut down the vast amount of experiments involved in the optimisation of back coating development.

Numerous computer programs are available, however, in our particular study "Maximise", developed by BTR was used. This technique allows all the experimental variables to be changed in a planned manner at the same time and this considerably reduces the number of experiments, in addition to giving much more information on the interaction between the various components of the back coating compounds.
Maximise has three methods of experimental design.

1. **Full Factorial Design:** This studies the main effects of each variable and measures the interactions between these.

2. **Fractional or Screening Design:** This type of experimental design is useful where there are a large number of variables and it enables the user to understand which of the variables is the most important.

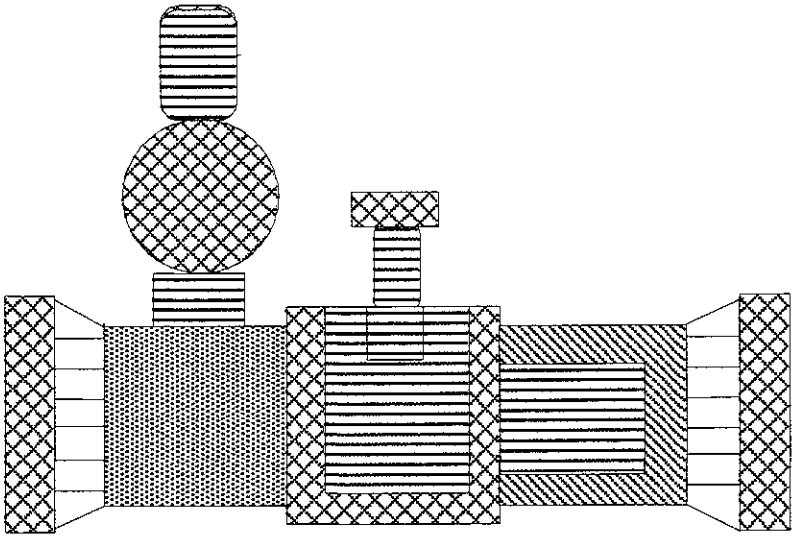

Figure 4: The gas cell

3. **Central Process Design:** This is used for the optimisation of formulations and for producing formulations, which simultaneously satisfy more than one set of criteria.

All three of these were used in our studies on the release of formaldehyde. The final stage in the analysis was to produce a formulation, which satisfied two important criteria; these were a flame retarded fabric having a Limiting Oxygen Index[2] value of not less than 28 (found by experience to guarantee a pass under typical vertical fabric strip testing conditions) and a formaldehyde emission during the curing reaction of under 5ppm. It is interesting to note that the final computer prediction from this analysis gave a formulation that had not actually been used in the experiments. When this formulation was tried in the pilot scale experiments, the computer prediction was found to be correct and indeed the aims of the study had been achieved. This is completely different from the conventional experimental approach, where the experiment, which gives the "best" result, is the formulation of choice.

Recipe Optimisation

4. One of the main objectives in all our experimental work was to ensure that whatever alterations were made to the formulation, the final product must remain the same. Thus it was decided that the minimum Limiting Oxygen Index that was required from any formulation would be 28. Experiments were performed on a whole variety of resins and formulations on the experimental scale to give a formulation, which had a minimum formaldehyde emission. The results of the final formulation are shown alongside the standard recipe in Table 1. **Central Process Design:** This is used for the optimisation of formulations and for producing formulations, which simultaneously satisfy more than one set of criteria.

Table 1: Standard and Optimised recipes

Component (g/litre)	Standard recipe	Optimised recipe
Pyrovatex CP	280	260
Melamine resin	35	32
Softener	25	27
Phosphoric acid	20	15
Wetting agent	1.25	1.25

The fabric results obtained from these trials were satisfactory and are illustrated in Table 2.

Table 2: Fabric results.

	Standard recipe	Optimised recipe
Limiting Oxygen Index	28	30
Percent phosphorus on fabric	1.9	2.0
Formaldehyde liberated (ppm)	20	5

Table 2 demonstrates that the main objective of the study had been met and that the formaldehyde levels had been reduced to 5ppm, whilst maintaining the limiting oxygen index. However, the technique had only been proved at the pilot plant scale and so it was decided that a full scale plant trial should be performed to ensure that the results from the pilot scale trials could be transferred. Three industrial finishing companies were chosen for these trials, all of whom had been operating the Pyrovatex process successfully for a number of years. The actual trials were done on commercial furnishing fabric and a 2,000m length of fabric was chosen. This represented about two hours running time on the actual plant. Formaldehyde levels were monitored throughout the runs and the final formaldehyde emissions are shown in Table 3 and show significant reductions in the levels of formaldehyde at all three locations.

It is interesting to note that all the fabric treated during the trials complied with all the quality control checks and was subsequently sold without complaint.

Table 3: Results of the industrial trials

Site	Standard Recipe Formaldehyde released ppm.	Optimised Recipe Formaldehyde released ppm.	Reduction %
1	11	4.5	59
2	7	4.5	36
3	4.3	2.5	42

LIQUID EFFLUENT

During the experimental work on alternative catalysts it was shown that ammonium phosphate was as an effective catalyst as phosphoric acid. Trials were then performed

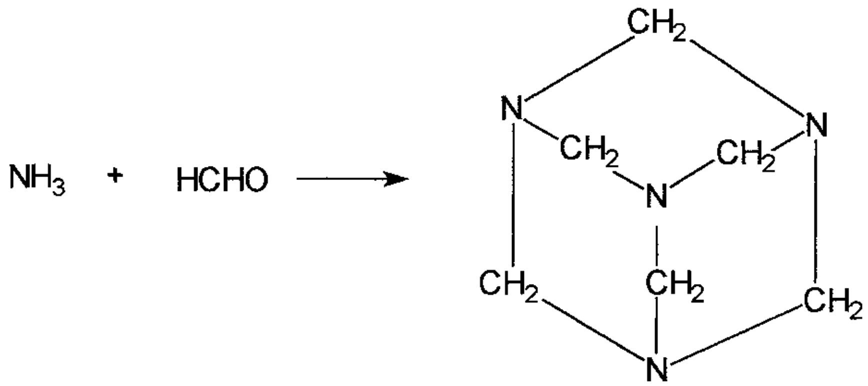

Figure 5: The reaction between formaldehyde and ammonia

using ammonium hydroxide as the neutralising agent after the pyrovatex cross-linking reaction, which occurs after the final product baking. The neutralised washing solution was then substituted into the original recipe and the catalyst reused. This led to a 60% reduction in the phosphate in the effluent . In addition when the fabric from these trials was evaluated a higher level of LOI was achieved and the formaldehyde emissions on the pilot scale were reduced to 2ppm. This is possibly due to the formation of hexamethylene tetramine from the reaction between ammonia and formaldehyde, as shown in Figure 5.

CONCLUSIONS

The use of chemometrics in the process optimisation has been successfully demonstrated, so that the emission of formaldehyde from the curing of the flame retardant Pyrovatex may be significantly reduced. One of the main advantages of the computer software used in these experiments is that is predicts an optimum which has not actually been part of the experimental program. It has also been demonstrated on an experimental basis that the effluent from this process may be considerably reduced.

Finally we have applied this particular software package to two other textile processes with equally successful results. The full resultsof this research programme are published as an ETBPP document (see Chapter 1 and ref.3).

Acknowledgements

The support of the Department of the Environment, Transport and the Regions under the ETIS program is gratefully acknowledged.

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SAVING WASTE MAKES MONEY

Brian Bruce

INTRODUCTION

We are all in business to make money - fact! So by saving waste in all forms we will save money. How will we know if we are successful? The most obvious measurement of success is money saved, therefore, we have to have some way of measuring what we are achieving. People talk about efficiency - *we run our companies/our factories efficiently*. What does this mean? A simple equation is what you get, less what you pay for; the difference between the two is efficiency.

Alternatively taking all the parts in the production equation - energy, raw materials, labour, management, marketing and waste disposal - these are all costs and the benefit of expending these costs is the production of saleable product. The difference between the two, again, determines efficiency. So whilst energy isn't the biggest part of our expenditure budget, savings on energy in whatever form go straight to the bottom line, and if £10,000 is saved on energy in one form or another over a year, this is an additional £10,000 which is pure profit. Similarly 1% or 2% waste reduction also goes straight to the bottom line.

How do we determine what we are spending now and what we ought to be spending? The only way that we can decide whether we are efficient or not is to monitor the usage of energy in all its forms - gas, electricity, gas oil, coal, water, steam and compressed air - these are all easily monitorable and can form the benchmark as to how we compare with others. Also what is our waste production daily/weekly looking at all aspects: - yarn, fabric, chemicals, dyestuffs, water, polythene, cardboard, and paper.

MEASURING ENERGY USAGE AND GOOD HOUSEKEEPING

Most factories have one meter to measure gas coming in, one for electricity and one for water. They don't know which machines in the factory are wasteful of energy, which are costing them the most. For example, recent studies of a number of dyehouses looking at different processes and different uses of energy show that out of 10 or 12 dyehouses, only one knew that the drying cans were costing them 1.1p per metre processed. This is the only company which can put an exact figure into its costing to make sure that it is recovering costs unit by unit, process by process.

The costs of putting in additional meters can vary between about £350 and £3,500 per metre, depending upon how sophisticated it is and how much detail you are looking for. However, most meters are of a portable type and can be moved from machine to machine. Initially a simple meter will give information to work on. Whatever is done, don't try to go for complex savings first. There are a lot of simple things that companies can do which will save them money. This is not to suggest that companies have not already examined their various activities, all are familiar with good housekeeping and all claim to do it. All companies sweep and clean factories up on a regular basis knowing that if the factory inspector is going to call, when he looks and sees a tidy factory he will not take any further interest in what you are doing within. Good housekeeping as well as keeping a clean factory also means switching off lights, putting in low voltage bulbs - to give the same light for less cost - turning off motors when they are not being used, looking at space heater usage - we all heat space but are we heating the space which is warming the people who work in our factory or are we heating large areas up in the roof, large areas where heat is going nowhere, achieving nothing. Most companies today consider draught-proofing, double glazing, putting in roof lagging, air conditioning and making sure pipes are all covered, but how many people look at switching off the compressors when the factory is not being used? One textile company whom started to monitor and measure the use of electricity and found that during the night quite a large amount of electricity was being used. They couldn't understand this because, although they had an electric burglar alarm with its infrared rays the usage was far higher than it should have been - they checked. The compressors were switched on at 6 a.m. on Monday and were left on until 6 pm on Saturday despite the fact that at that moment in time they were only working a single shift, so for 16 hours every day compressors were being kept fully operational when no-one was there. It is easy to overlook factors like this, which like other services, are often taken for granted.

CASE STUDIES OF WASTE MINIMISATION

Below are some examples of energy and waste savings in textile factories which have taken place, some at low cost, some at a very short pay-back cost and some which were highly lucrative in terms of savings but did have quite a high expenditure rate in order to achieve them.

Under the UK Environmental Technology Best Practice Programme, there have been some successful textile case studies produced. One at the Standish Company in Wigan and an other one at Toray Textiles in Nottingham. Toray Textiles, since they started their energy management programme in 1989, have produced energy savings of more than £684,000 and half of these savings are through measures involving little or no capital expenditure. The company's site at Bulwell uses several different energy sources for dyeing and finishing. They use interruptible gas and gas oil for steam raising, firm gas to fuel the stenters and electricity for power and lighting. They have achieved over half of this large amount of savings by looking at good housekeeping measures, as stated earlier, such as switching off lights, turning off process motors and plant when they are not in use and they also then examined six capital areas for investments. These included attention to the scouring machines, a stenter, boiler flues, dyeing vessels, dyeing machines and a condensate return. Overall a 27% reduction in energy cost was achieved in less than 5 years through a combination of good housekeeping, involving the workforce in what they were doing, capital investment projects and a monitoring regime to maintain efficiency improvements.

At Standish investigated their bleach ranges and by modifying the pre-dyeing processes and made savings of £25,000 a year of energy and £10,300 a year in water savings. The payback period on investment costs of £12,500, was six months for energy savings alone or 4½ months for all savings. Their process started with desizing which removes contaminants, which had been put in during the weaving. These include starches and other chemicals, which are there sometimes from overseas producers to reduce attack by mildew or moulds during transport; they also condition the fabrics to improve dyeing. The fabric is transferred through a series of scour baths where it is treated with an alkaline solution and then through a series of bleaching and washing baths prior to dyeing. Until recently the scouring and bleaching stages each required a separate intake of mains water after which the effluent was discharged straight to drain. Despite the use of heat recovery, considerable quantities of steam are required in order to heat the incoming mains water to the temperatures necessary for carrying out the process.

The company's engineering department demonstrated that the hot effluent from the washing phase of the bleaching process could be diverted to provide scouring wash water. This modification resulted in a halving of water consumption, which obviously led to reductions in water charges, and in effluent costs. The use of the pre-heated wash water in the scouring section also had a significant impact on steam consumption and a reduction of 42% was achieved for this phase of the process. This gave overall savings of £38,800 a year mentioned above, giving a payback period of 4½ months. This process can be carried out in a number of areas in the dyeing and finishing industry. It can also be carried out of course in many other industries where water is a major part of their process. Copies of these case studies are available from ETSU at Harwell, UK

A third textile company started in 1994 to consider possible energy savings. Initially they were hoping to find savings of 15% per annum but in year one they managed to achieve overall energy savings of some 28%. They also produced a 20% saving on the amount of water used.

Initial examination of process control computer programmes and suggested a reduction in the number of washes at the end of the process. By adjusting the programmes they managed to save annually about £1,700. They stopped "pulling the plug" and releasing wash water each time they came to the end of a process, and by reusing the water used in the last rinse in both their winch and their beam dye ranges, they produced again substantial savings, some £2,700 per annum.

Subsequent studies of the chemicals used in the process enabled reductions to be made and by recycling the bearing cooling water and putting it back into the lodge or a holding tank, they were able to save both water and energy.

They diverted the pipes - underneath their bleaching and dyeing machinery were two drains, water was running straight from the factory floor and also from the processes into these drains. In order to make sure that only clean water was being saved, pipework was diverted for clean water to pass to a clean water sump which was able to be re-used and only dirty water and went straight to effluent. Furthermore, by optimising the back-washing of filters in their bore-hole enabled reduction of the amount of filter cleaning that was needed and of the number of flushes each time the filters were cleaned. Overall the six steps have saved £10,000 per annum which is a direct benefit, and appears on the bottom line.

A fourth company, which is based in Yorkshire, used to allow their jig dyeing machines to overflow as part of the washing process and by installing a pulse action during the wash-off this stopped the water from overflowing. This saved the company 1,000 cu. metres of water per week which translated into overall savings of £32,000 per annum. Another company in Yorkshire, by checking the amount of chemicals and dyestuffs used, are now able to reduce the amount of each used per batch, which has two benefits, more of the dyestuffs and chemicals are absorbed onto the fabrics and this means that less washing-off is required, generating a saving on each batch.

While examples above are, in the main from the dyeing and finishing sector of our industry, this is not to say that considerable savings can't be made in the spinning and weaving areas - the recycling of carding and combing waste in the spinning sector, measured lengths when producing beams in weaving, putting bar codes onto the ends of rolls of fabric instead of wasting 200-250mm off each piece in order to provide identification marks - these are some of the basic ways in which waste can be minimised in the spinning and weaving area. By working more effectively, by getting right first time as part of their quality control system, there are energy and waste savings also to be made - good housekeeping saves in every type of factory.

ENERGY/WASTE MANAGEMENT SYSTEMS

We have measured our energy usage, examined waste, monitored all activities in the factory, so where do we go from here? The next stage is to consider putting into effect an energy/waste management system (haven't we got enough systems in the factory already). In the first place, the system should not be extremely sophisticated, although it may become more so as years go by. It is an eight-step process:

(i) Step one is to give somebody the responsibility of energy/waste management. For most companies, particularly small and medium sized enterprises (SMEs); there is no need for this to be a full-time job. A member of staff can be trained and given this management role as an additional or complementary responsibility. It is important that the individual has the authority and resources to do the job properly together with a good understanding of the way your company and its processes work.

(ii) Step two is to establish the size of the problem and hence responsibility. In order to gain commitment to make savings, to make it part of the management programme, quantification of energy usage, waste produced and its cost and estimations of what can be achieved quickly and easily by altering production/operating methods are required. Management commitment should be demonstrated at this stage through the inclusion of an energy/waste management policy within the overall company's environmental policy where one exists. No company is too small to have a minimisation policy.

(iii) Stage three is to identify the current position by putting into place an auditing system. How much energy is being used overall? How much is being used in each department on each process? How much is being used by a particular type of machine within each of those departments? How much waste is produced throughout the factory within each department? Obviously in order to make this satisfactory it is important that records are kept, ideally on a daily basis. It may be that records can be kept by the departmental supervisor and passed onto the manager on a daily or weekly basis. These can then be correlated and a picture gained of the energy utilisation waste production through each of the departments.

(iv) Analysis of the audit findings is the fourth stage. The resulting data should be in the form, which is understandable by everyone inside the factory.

(v) Five - consider the options. Having gained a proper understanding of the energy utilisation and waste production and the places where it is used/generated inside the factory, it becomes possible to prioritise areas where savings can be easily made often at little or no cost. Once people see savings, ownership of the energy utilisation and waste production in the department, by the supervisors and operators, is easily or more easily generated, then the company is a long way down the road of making savings. When as a student many years ago, people used to leave rubbish, paper, apple cores, orange peel, on the floor and I heard it said that we employ a cleaner to clear this rubbish up and if we don't leave waste then there is no job for the cleaner. It wasn't true then, it isn't true now and if people are prepared to work together to turn off lights, to turn off motors, to make sure that the simple things are being done then progress will be made. If the management has a conservation team, which consists of people from different departments and different levels of authority within the organisation work together, then a realisable action plan will follow.

(vi) Step six is to prioritise the actions required to be taken.

(vii) Having decided this is our action plan step seven is to get everyone involved in this plan, from the Managing Director down to the cleaner and make everybody aware of the benefits, improved profitability, better job security etc. This may be done through the use of presentations, through newsletters or notice boards, making sure that people constantly get feed back on what savings have been made in order to keep their interest. Again it really depends on company size as to which is the best way and it is only that specific company and its own personnel that can decide the way forward.

(viii) Step eight is to review the progress. The action plan has been implemented against the targets that the team has set, initially on a six-monthly basis and perhaps later on a yearly basis. It is helpful to review how successful the auditing has been. Is the data collected as accurate as it can be? Is the relevance of what is being collected as relevant is it might be? Thus having reached stage eight the team must go back and look again at step three. Can the auditing system be improved to enable progress to be made more quickly?

These steps in energy and waste management point the way forward for savings over the years to come.

One company put into place an auditing system and they actually got down to putting measurements on all of the various machines and over a 2 year period there was one particular section where they were having real problems. Excess energy was being used and they couldn't understand why. It was using twice as much sometimes three times as much energy to run this particular section as it should have done. They then had a look at each machine in greater detail. They found there was a leak on one machine and electrical energy was leaking away to earth. By correcting this leak significant savings were made and again the process became as efficient as could be expected and again money saved went to the bottom line.

In conclusion, therefore, to be economically and environmentally viable, measure what is happening in your factory. Monitor the use being made of energy and raw materials in the factory. Target areas for improvement and put into place action plans and control that improvement on a continuous basis. If looking for yearly savings, monitor monthly. This will then show that an economically efficient company is also environmentally efficient.

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