WR1403: Business Waste Prevention Evidence Review

L2m6 – Hazard Reduction

A report for
Defra

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This report has been prepared by:	David Parker, Helmut Sengstschmid
Checked as a final copy by:	Katie Deegan
Reviewed by:	Nick Morley
Date:	22 October 2011
Contact:	helmut.sengstschmid@oakdenehollins.co.uk
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Context of Project WR1403

Waste prevention is at the top of the waste hierarchy. A major priority of the coalition government is to move towards a zero waste economy, and an important element of this will be to encourage and increase waste prevention. This review aims to map and collate the available evidence on business waste prevention. It will help inform the preparation of England's National Waste Prevention Programme as required under the revised EU Waste Framework Directive (2008).

The focus is on aspects of waste prevention that are influenced directly or indirectly by businesses - it complements a previous evidence review, WR1204, which focused on household waste prevention. The definition of the term 'waste prevention' used here is that in the revised Waste Framework Directive:

'Prevention' means measures taken before a substance, material or product has become waste, that reduce:

- *a) the quantity of waste, including through the re-use of products or the extension of the life span of products;*
- *a) the adverse impacts of the generated waste on the environment and human health; or*
- *b) the content of harmful substances in materials and products.*

Recycling activities or their promotion are outside the scope of this review.

Context of this module

This module is one of a number of Level 2 modules that contain analyses of Approaches, Interventions, Sector Issues and other aspects of the review. This module deals specifically with the aspect of Reduction of Hazardousness of process waste and emissions, and content of products.

A full map of the modular reporting structure can be found within **L1m2: Report Index**.

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Contents

Glossary

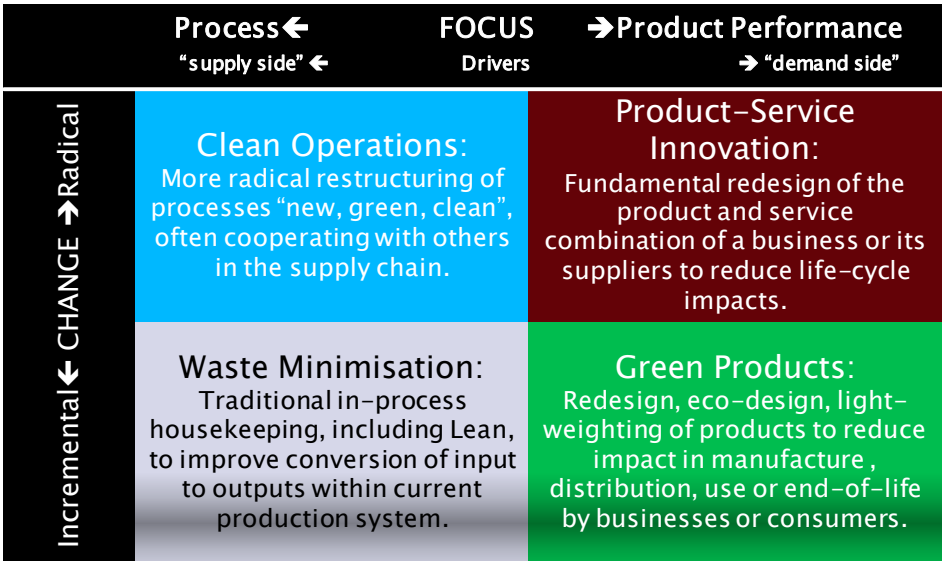
BREW	Business Resource Efficiency and Waste (programme)	PVC	polyvinyl chloride
CIA	Chemical Industries Association	R&D	Research and development
CMS	Chemical Management Services	REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
DTI	(former) Department for Trade and Industry	RoHS	Restriction of Hazardous Substances (Directive)
EA	Environment Agency	SME	Small/medium sized enterprise (EU definition)
ELV	End of Life Vehicle (Directive)	SPM	Sustainable Products and Materials (DTI call)
EPR	extended producer responsibility	TSB	Technology Strategy Board
EPSRC	Engineering & Physical Sciences Research Council	US EPA	United States Environmental Protection Agency
ICCA	International Council of Chemical Associations	VOC	volatile organic compound
LOCOG	London Organising Committee of the Olympic and Paralympic Games	WEEE	waste electrical and electronic equipment
NISP	National Industrial Symbiosis Programme	WMM	Waste Management & Minimisation (DTI call)
		ZEE	Zero Emissions Enterprise (DTI call)

Units Conventional SI units and prefixes used throughout: {k, kilo, 1,000} {M, mega, 1,000,000} {G, giga, 10^9} {kg, kilogramme, unit mass} {t, metric tonne, 1,000 kg}

Language used in this report

This report has used a framework for evaluating both the actions a business takes to prevent waste (the Approaches), and the mechanisms that have catalysed the actions (the Interventions). The detailed description of Approaches and Interventions may be found within the respective modules **L2m2: Approaches** and **L2m4-0: Interventions Introduction**, but a brief reference outline to the Approaches is given here:

Positioning of approaches in response to business drivers including waste



Source: Oakdene Hollins/Brook Lyndhurst

1 Introduction

The Waste Framework Directive obliges EU Member States to consider hazardous materials within the scope of waste prevention. Reduced hazardousness is deemed a desirable objective even if it results in increased weights of non-hazardous waste. For the purposes of this work, we have considered the following two classes of hazardousness:

- Hazardous wastes arising from and during the manufacture or processing of materials. Reduction could be achieved by switching to an alternative manufacturing system not involving hazardous materials as well as simply reducing the hazardous materials to a minimum within the current system by sound management or recovery.

- Hazardous content of products of manufacture which might cause environmental or health damage during use or after disposal. Reduction could be achieved by simple lowering of content; pro-rata lowering by light-weighting or substitution by a lower hazard alternative. A more radical alternative could be the isolation of hazardous components such that their recovery and possibly reuse at end of life could be managed, thus also avoiding further manufacturing wastes.

Examples of both approaches in concert have been found.

We also note that significant volumes of legislation have been compiled which place mandatory obligations on businesses. These Directives are not within the scope of this work, which concentrates on measures taken without coercion. However, for completeness we note the publication by the EU of parallel work which has investigated waste prevention within the community, including hazardous waste.[a] The following Directives have – to a greater or lesser extent – a direct bearing on hazardous wastes and content:

- Batteries Directive (2006/66EC)
- End of Life Vehicles (ELV) Directive (2000/53/EC)
- Mining Waste Directive (2006/21/EC)
- Packaging Directive (1994/62/EC)
- Waste Electrical & Electronic Equipment (WEEE) Directive (2002/96/EC)
- Restriction of Hazardous Substances (RoHS) Directive (2002/95/EC)
- REACH Regulation (1907/2006)
- Regulation on ozone-depleting substances (1005/2009)
- Eco-design of energy-related products Directive (2009/125/EC).

As stated, our work has focused on voluntary measures with the expectation that the following drivers would become evident:

- **Financial:** Cost-saving measures aimed at waste prevention that have side-effects of hazard reduction.
- **Commitments:** Sector- or regional-based agreements to take action on specific or general hazard issues.
- **Standards/Labelling:** Purchasers take account of existing hazard labelling or labelling systems designed to promote low impact goods and services and use this to 'choice edit' suppliers.
- **Procurement:** More widely, purchasers choose low impact goods and services because of their own ethos or because of the 'pass-through' risks to their own customers i.e. their corporate social responsibility profile.

[a] http://ec.europa.eu/environment/waste/strategy.htm [accessed January 2011]

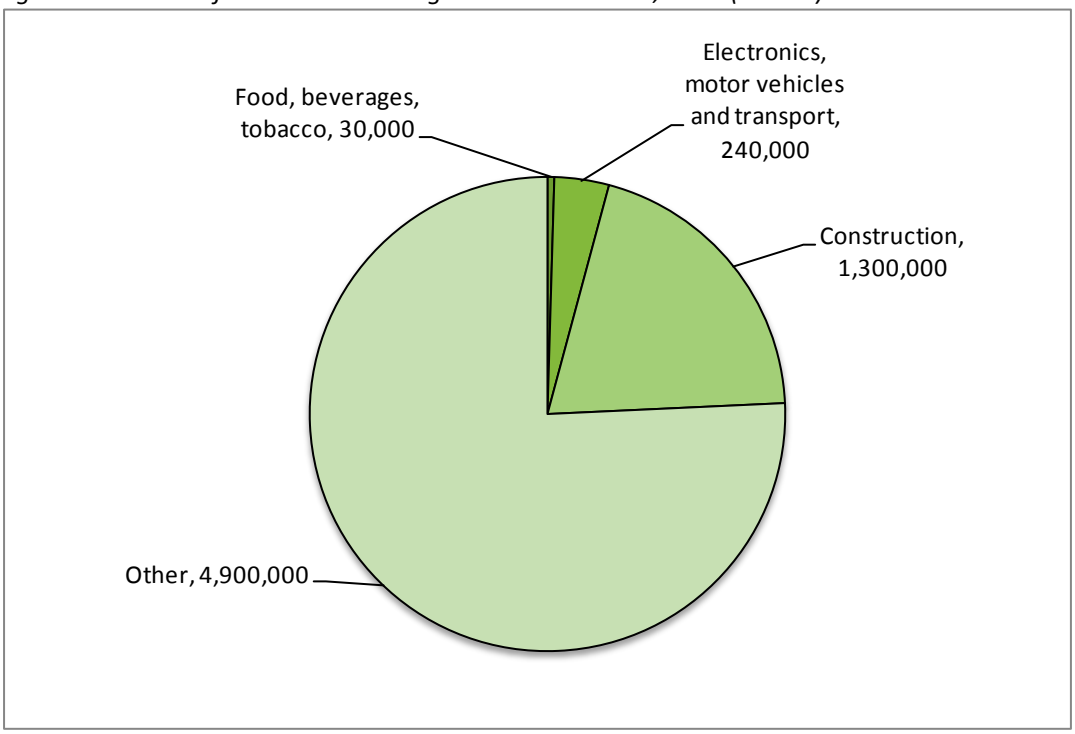
2 What is the Importance of Hazardous Waste?

Hazardous waste has deservedly received attention from both Defra and the Environment Agency (EA). Both agencies have sponsored initiatives to both track and target areas of highest arisings and impact. In the early 1990s, the Environmental Technology Best Practice Programme – even though it concentrated on energy and water savings - formed a basis of work in the area. The advent of Integrated Pollution Control would also suggest there has been increased awareness of hazard reduction drivers through the 1990s.

More recently, the EA's HAZRED initiative, sponsored under the EU LIFE programme in 2005, characterised and prioritised action on hazardous wastes from a range of business sectors (1). With a particular emphasis on SMEs, the project established waste reduction targets and plans by sector. The resulting pan-EU LIFE programme report identified at least 1,200 tonnes of hazardous waste savings in the UK (2). The EA has continued to maintain an interest through initiatives such as European Pathway to Zero Waste targeting high-impact sectors such as construction. Likewise, Defra's Hazardous Waste Forum maintained a watching brief on arisings and commissioned work to assess volumes across a number of sectors (3).

In 2008, approximately 2% of the UK's waste (6.4 million tonnes) was classified as 'hazardous'.[a] An overview of the sectors generating hazardous waste is given in Figure 1. Of the sectors in the scope of this study it is the construction sector that generates the largest amount of hazardous waste (1.3 million tonnes per year), with contaminated soil (25%) and asbestos (10%) the most common hazardous waste types in this sector (4). The automotive industry is reported together with 'Manufacturing of Electronic and Electric Equipment' which produces about 240,000 tonnes of hazardous waste per year. The food, beverages and tobacco sector is responsible for 30,000 tonnes per year of hazardous waste.

Figure 1: Amount of hazardous waste generated in the UK, 2008 (tonnes)



Source: Eurostat

[a] Eurostat, 2008

As noted in the introduction, hazardous waste has received considerable regulatory attention. The reduction on landfills taking hazardous waste was occasioned by the Landfill Directive implementation banning UK co-disposal techniques, and was a powerful incentive to ensure waste classification (hazardous vs non-hazardous) was accurate.

Outright substance prohibitions have been more directed at the hazardous content of products, their health impacts in use and in disposal. Those regulations tackling the processes, systems and disposal obligations appear more oriented to waste arising from manufacture. In response to the latter, there have been a number of sector-based initiatives that appear to be voluntary but which might, nonetheless, appear to be pre-emptive of stronger legislation. One high profile example is that of the global chemicals industry, co-ordinated by the International Council of Chemical Associations (ICCA), which instituted the *Responsible Care™* programme. This addresses the broad environmental and life-cycle impacts of chemicals manufacture and use, energy, wastes etc. although hazardous wastes *per se* are not enumerated in the annual reports (5; 6; 7). Globally, wastes do show a falling trend and, given the weight of other legislation in the field, it is not unreasonable to assume that hazardous components are also falling.

3 The Nature of the Evidence

The evidence review for this report is informed by a range of case study, web publications and programme reports. We acknowledge that it is significantly influenced by North American (US) literature. This should not imply that little has been done in the UK compared to elsewhere, but reflects the following:

- There is a degree of openness in North America based on various legislative drivers such as 'community right to know' which is conducive to dissemination and even advertisement of compliance efforts.
- The core sectors of our search scope mean that certain sectors – such as automotive – were highly represented, but corporate reporting centres are located abroad.
- The timescale of our search meant also that some excellent historic materials which related to a broad range of metals, engineering and allied sectors were not gathered.

After the data-gathering phase, a number of case studies from the Envirowise archive were made available to us, but which we were unable to include within the analysis:

- "The development of a fully-contained bulk supply system for industrial coatings." (VOC elimination)(Envirowise document: FP1)
- "The results of a good practice case study at MBC Precision Castings" (solvent replacement)(GC14)
- "The results of a good practice case study at British Steel Engineering, Fullwood Foundry" (VOC elimination; sands, resins use & disposal)(GC23)
- "A new practice case study at Goldrite Metal Finishing Ltd" (plating chemical savings)(GC14)

Accordingly, we reiterate that the balance of evidence does not indicate that the UK is a laggard in respect of hazardous waste management by prevention.

4 What are the Approaches?

The generation of hazardous waste is not just seen as a waste problem, but is also a major focus of pollution prevention initiatives. Consequently, the cost of hazardous waste generation – both financially and in respect of reputation and license to operate – has been recognised by businesses. As early as 1989, a study by the US EPA showed that 37% of businesses producing significant amounts of hazardous waste were investigating ways to minimise waste by source reduction or recycling (8).

4.1 Waste Minimisation

Improvements in process efficiency are the most often cited approach to source reduction of hazardous waste in two studies of the US industry (9; 8). Most of these changes are not technical in nature but involve modified procedures or practices. Some are general in nature, like implementing the legal requirement to stop the combination of hazardous and non-hazardous waste. However, most involve bespoke actions requiring in-depth process knowledge, which makes them less accessible to a 'quick-and-dirty' business support approach. Additionally, training of the shop-floor staff is both crucial and often highly effective (e.g. 50% reduction in paint waste in SMEs through better training and small improvements (10)).

A different approach is in-house recovery from hazardous waste using operations like distillation of spent solvents; this is employed widely in the chemical industry, but also in small car repair shops (11). By analogy, the construction sector has long had a problem with excavated materials classed as hazardous waste. Technology has been developed to facilitate separation of the most hazardous components allowing reuse of the remainder on site (4). This has been the subject of support by, amongst others, the Technology Strategy Board's (TSB) Technology Programme (12). Sometimes it may even be sufficient simply to assess the actual risk involved in redeploying, for example, contaminated soil, to reveal the possibility of alternatives to hazardous treatment (13).

Hazardous waste reduction can also be achieved by outsourcing the management of the use of hazardous chemicals to third party agents. From the perspective of the business concerned, this is classed here as waste minimisation. From the perspective of the third party, it is a product/service innovation. In order to provide appropriate differentiation of such pioneering efforts, the known examples are covered in Section 4.4.

4.2 Clean Operations

There are many examples of tackling hazardous waste by means of clean operations. Most of these are not through technical innovations in-house, but through substitution of hazardous process chemicals by less harmful ones (8), although the main driver for this is prohibition (or its threat). Similarly, in the case of a Finnish company producing industrial tooling, the (re)classification of a waste fraction as hazardous waste was reported to have led to the substitution of a raw material with a less harmful but more expensive one, but leading to overall lower total process expenses (14). Other common examples include the substitution of heavy metals (15; 16; 17), mineral oils (18), and organic solvents (19).

An important aspect of avoiding the use hazardous substances in production are the additional benefits of reducing health and safety risks to the employees handling these chemicals, as well as emissions to the environment (10). Besides a substitution of acknowledged hazardous materials, some companies have started to substitute suspected hazardous components with ones with perceived lower impact. An example is the switch from styrofoam to cornstarch-based foam packaging by Toyota Freemont (US) (20).

A different approach to reduce hazardous waste is to develop technologies to allow separation and decontamination of hazardous components or materials in used products to allow their re-use or recovery:

- The TRAFODECON project established a new technology to decontaminate old transformers containing persistent organic pollutants and to re-use them, thus reducing the amount of hazardous waste being produced and reducing replacement costs by approximately 50% (17).
- A similar example, but on a much smaller scale, involved switching from single-use tissues for wiping down machinery to washable cotton wipes (16).

HAZRED was a three-year EU-funded project delivered between December 2004 and November 2007. Its main focus was to reduce hazardous material generation in SMEs from six priority sectors. Approximately 1,200 tonnes of hazardous waste were diverted from landfill and savings to business totalling more than £440,000 in the UK. Two given examples are:

- Ashton & Moore Ltd provides protective finishes on metal components for the aerospace sector and it developed new chrome-free treatments and alternatives to cyanide-based paint stripper.
- Greenhouse Graphics, which offers in-house commercial design and print facilities, invested in a new printing press that cut isopropyl alcohol use by up to 75%. They also switched to non-VOC solvents for cleaning the press, reducing hazardous emissions (2).

4.3 Green Products

An important driver towards minimisation of hazardous waste via product redesign is extended producer responsibility (EPR) legislation. EPR Directives specify thresholds for the use of hazardous substances in certain products and place obligations on manufacturers and importers to collect and recover their products when they become waste (21). This is intended to encourage businesses to consider the end-of-life impacts of their products at the design stage. For example, the material restrictions outlined in the RoHS Directive which accompanies the WEEE Directive have resulted in a global effect on hazardous chemical substitution as reported in an EU-Canadian comparison (22).

In a similar fashion, Sweden's 1993 ban of mercury switches in vehicles, followed by an EU-wide ban within the ELV Directive in 2003, led to a phase-out of mercury switches in Europe. In the US, where no such regulatory pressure was applied, such components were still being installed in new cars after 2000 and only some companies phased out mercury switches voluntarily (e.g. Daimler Chrysler) (23).

Voluntarily adopted standards – which often become part of public procurement criteria – usually have tight rules regarding the use of hazardous substances in production processes. For example, an impact assessment of the European Ecolabel estimated that a market penetration of 5% of eco-labelled goods would reduce hazardous materials by 14,000 tonnes directly and approximately 40,000 tonnes indirectly, if adopted by the private and public sectors (24).

However, the overall use of eco-design to reduce hazardous waste is limited: Product modification was one of the least often chosen approaches of waste minimisation practices by companies on the US Toxic Release Inventory (9). An interesting counter-example is that of rendering a hazardous corrosion inhibitor obsolete by changing the material of the product from steel to plastics (25).

Most of the examples we have identified relate to substituting a hazardous substance with an equivalent non-hazardous material, sometimes including a modification of process equipment. A widely quoted example is that of paints where there has been a general move from solvent- to water-based systems, which affects not only the exposure of the paint user, but also radically alters the processing of the materials in production. In this area, therefore, there is often a strong interaction between product and process design (green products and clean operations). A significant recent example is the elimination of

solvents from paints in a collaborative project between ICI Paints and Carillion, sponsored by the TSB's collaborative R&D programme, Zero Emissions Enterprise theme (26).

4.4 Product/Service Innovation

Within the limitations of the scope of our search, we found no examples of businesses with hazardousness issues employing in-house product/service innovation to tackle the issue. However, as a complement to the relationship between green products and clean operations identified above, we observed that there are numerous examples of third parties offering innovative services to manage the hazardous materials of other businesses i.e. a waste minimisation/product service relationship. One of the most significant offerings of the last ten years in the UK (though significantly more advanced in the US) is Chemical Management Services (CMS).

As the name implies, CMS involves a supplier of chemicals taking substantial responsibility for the specification, use, recovery and even reuse of those chemicals by their customer. This may be driven by actual or impending legislative pressures, but is typically sold as a financial opportunity for both parties, with performance incentives linked to a baseline consumption which reduces over time. CMS has made substantial inroads in heartland engineering such as automotive, aerospace, electronics, food and drink and machine shops sectors, where the application of chemicals is not a 'core competence' and may safely be out-sourced to a third party without threat to operations. Typical chemical duties covered include water treatment, surface preparation and finishing, paint shop management and cutting fluid management.

According to CMS Forum's 2004 Industry Report, typical client savings are 6-10% per year, largely attributable to reduced chemical usage. Whilst absolute figures on hazardous waste are not available, this does provide a strong indicator of the potential, especially given that Europe and Asia are less culturally receptive to the concept than the US (27).

Box 1 presents a case study in CMS provided by International eChem (28). This approach is not overtly dedicated to hazardous waste reduction, merely indicative of the CMS principle. As indicated above, we were unable to locate robust case study materials that were sufficiently specific on hazardous waste elimination rather than cost savings. However, the Rohm & Haas company website[a] contains a number of case studies which refer to various materials such as paints, solvents and cleaners which typically require special waste treatments.

The aspect of reuse can have a valuable role. We have located a number of examples both of reuse of chemicals by other parties (which is marginal to the scope of this work) and of onward sales of excess or 'past sell-by date' materials. One such example (amongst a number in this genre) is provided by NISP (29): The Anglo-Norwegian biotech firm Axis-Shield passes on excess chemicals (still within their use-by dates and frequently unopened) from one of its UK sites to a different company in the same sector, Alchemy Laboratories Ltd, which is located nearby, to mutual advantage.

[a] http://www.haastcm.com/case-studies/casestudies.html [accessed 7 June 2011]

Box 1: Thames Water & CIBA Specialty Chemicals - CMS pilot program

Thames Water and Ciba Specialty Chemical (CSP) entered into a service-based agreement at a pilot Thames plant, the Swindon Treatment Works. The program focuses on the sludge dewatering process and program benefits include a reduction in sludge volume of >15% on average compared to before the pilot with a corresponding decrease in sludge transport and processing costs of >20% per year. There is the potential and expectation to roll out the program to over 100+ similar plants within Thames Water.

Business Benefits

- Costs savings in excess of 20% of current chemical spend per year after the first year.
- Service arrangement captures value upstream and downstream of sludge dewatering; there is now a system and incentives in place for continuous improvement.
- Environmental benefits of less sludge produced and a more stable final percent solids in sludge to reduce risk of failing to meet increasingly stringent environmental legislation.
- Gained supplier expertise in chemistry with Thames able to focus on wastewater and water engineering and operation.
- Potential for significant energy savings for sewage treatment works where sludge is dried.

Drivers for Initiating a Program

Thames Water	Ciba Specialty Chemicals
• Control increased sewage volume and chemical costs • In line with goals of operational excellence and innovation • Reduce risk and environmental impact • Yorkshire Forward funding provided outside expertise and helped decrease implementation costs	• Built on long term strategic partnership with customer • Increased understanding and integration with TW's processes • Promotion of Unique Selling Point • New business opportunities • Yorkshire Forward funding provided outside expertise and helped decrease implementation costs

Key Elements for Success

- Transparency and trust are fundamental to success.
- Value mapping and a lifecycle approach ensures you capture the true cost of ownership of chemicals.
- Clearly define success criteria.
- Accurate measurement is key.
- International eChem and CSP played a critical role by undertaking the underlying analysis of costs, and acting as trusted adviser to both parties.
- Upper management support at the earliest stage is critical.

Source: Courtesy of International eChem

5 What is the Evidence of Impact?

5.1 General Overview

An overview of two general studies on the prevention of hazardous waste in the USA is given in Table 1. No similar study was identified for the UK.

Table 1: Prevention of hazardous materials – general studies

Study	Achieved saving by prevention of hazardous waste*	Comment	Ref ID
Global study on pollution prevention involving 134 case studies	3,900,000 €/yr	12% of interventions involved substitution of toxic raw materials	(30)
US: registry of large-quantity generators of hazardous waste	3,000,000 t/yr	Underestimate, as only first year savings counted	(8)

* *Includes savings from reducing the use of hazardous materials*
Source: Collated by Oakdene Hollins/Brook Lyndhurst

5.2 Business Support

Many studies reporting on hazardous waste prevention have been undertaken to investigate the successes of various business support programmes. An overview of achieved reductions in hazardous waste by such programmes is given in Table 2.

Table 2: Prevention of hazardous materials – business support programmes

Business support programme	Achieved savings by prevention of hazardous waste*	Comment	Ref ID
BREW 2005/2006	120,000 t	Attributed savings – actual savings could be higher. 90% of this change is reported as having been achieved by the efforts of NISP.	(31)
BREW 2006/2007	146,000 t	Attributed savings – actual savings could be higher.	(32)
Envirowise (2005)	131,000 t	Of this total, approximately 12,000 t was attributed to the supplementary assistance of Envirowise	(33)
Massachusetts Office of Technical Assistance for Toxics Use Reduction	23,000 tons/y	Intervention by the agency caused a 9% larger reduction in toxic materials than stand-alone efforts of companies	(34)
Nebraska (US)	360 l/yr – 2,600 l/yr per client	Strong correlation between intensity of support and waste reduction achieved	(35)
Enviroclub (CAN)	708 t	SMEs	(10)
Clean Production Programme (West Australia)	48% reduction	Focus on SMEs in dry cleaning	(36)
Canadian Automotive Pollution Prevention Programme (CAN)	1,500 t/yr	Automotive sector	(37)

* *Includes savings from reducing the use of hazardous materials;*
Reported savings are, unless indicateded, total actual savings by participants; the ascribed or attributed fraction of the benefits claimed by the assisting agency may be less according to the reporting methodology. See Comments or refer to original source for details.
Source: Collated by Oakdene Hollins/Brook Lyndhurst

5.3 Incentives

Hazardous wastes have also been the subject of R&D programmes, in the UK largely funded by the Engineering & Physical Sciences Research Council (EPSRC), the former Department for Trade and Industry (DTI) and its successor, the Technology Strategy Board (TSB). DTI in particular received around £30 million in funding from Defra's BREW programme to grant support projects in the waste minimisation, clean operations and green products themes. These are dealt with in more detail in the **L2m4-6: Incentives** module, but some projected headline figures are quoted in Table 3 relating to:

- EPSRC/DTI's Sustainable Technology Initiative
- DTI's Waste Management & Minimisation call (WMM)
- DTI's Zero Emissions Enterprise call (ZEE)
- DTI's Sustainable Products and Materials call (SPM).

Table 3: Hazardous waste reductions from R&D programmes

Incentive programme (grant supported R&D)	Achieved savings by prevention of hazardous waste*	Comment	Ref ID
Sustainable Technologies Initiative	10,000 t/yr	Funding of collaborative R&D for lower environmental impact technologies (no special focus on hazardous waste)	(38)
WMM (projected benefits)	>50,000 t/yr	Assumed only 20% were preventative	(12)
ZEE (projected benefits)	Ca. 40,000 t/yr	Assumed only 50% were preventative	(12)
SPM (projected benefits)	Ca. 40,000 t/yr	Assumed all were preventative	(12)

Source: Collated by Oakdene Hollins/Brook Lyndhurst

5.4 Voluntary Initiatives

A good range of evidence has been found that commitments and voluntary agreements have helped prevent hazardous waste:

- In 2004, the UK Chemical Industries Association (CIA) launched "new guiding principles and goals for sustainable development" which included a commitment "by 2010, to achieve a 25 per cent overall reduction in hazardous waste, a 20 per cent reduction in water use, and 11 per cent improvement in energy efficiency; together with a significant reduction in our environmental burden" (39 p. 134). The CIA's initiative is part of *Responsible Care©*, "a self-imposed commitment by chemical companies worldwide under the auspices of the International Council of Chemical Associations (ICCA)" (39 p. 134). The specific actions triggered by this commitment – and their outcomes – are not known, although the CIA's website reports the following: "*The latest Environment Agency Spotlight Report, published in September 2008, showed that 98% of chemical sites were high scoring in environmental achievement and that we continue year on year reductions in our emissions of pollutants into air and water. The total waste produced and landfilled has reached an all time low and the proportion of waste recovery has increased*" (40).

- One of objectives of the Clean Texas 2000 program initiated by the Texas Natural Resource Conservation Commissioners in 1992 with 76 charter members was to "achieve a 50% reduction in releases of hazardous waste and toxic chemical releases reported in Texas by the year 2000" (41). The program "eventually covered 195 facilities, all of which achieved the reduction goal in 1997" (42).

- Hazard reduction has been an objective in the preparations for London 2012 Olympic Games. As well as committing to zero waste to landfill, the organising body LOCOG requires suppliers of PVC to demonstrate that the material "has been manufactured in accordance with the *ECVM* [European Council of Vinyl Manufacturers] *Industry Charter* for the Production of vinyl chloride monomer and PVC". The Charter requires that the material is made with minimal toxic impacts and its non-recycled content contains no "lead, mercury or cadmium stabilisers" (43). In addition, LOCOG "decided, as a matter of choice, to use reasonable endeavours to procure PVC which is produced using non-phthalate plasticisers". This is a valid example of waste prevention since the agency is with the procurer. LOCOG stresses that the stipulations are in addition to the requirement that "all chemicals used in the production of PVC must be registered or pre-registered for use under the REACH regulations with the European Chemical Agency". Additional LOCOG conditions regarding minimum recycled content and take-back schemes for the PVC are also set out, but are beyond the scope of this report.

- Some retailers (such as Marks & Spencer) have committed to phasing out PVC altogether from their packaging and products (44 p. 62).

- Global consumer and office products manufacturer 3M, which sets itself "tough operational targets" every five years as part of its 'pollution prevention pays' programme, developed 'Super Sticky notes' after assessing the life-cycle impacts of its famous *Post It*^{TM} notes. The new product uses a water- rather than solvent-based adhesive which both "improves factory safety as it eliminates the risk of explosions and fires caused by solvents" and "overcomes the issue of recycling/disposing of the solvent afterwards" (45).

- As part of an in-house commitment to prevent waste, the automotive company Toyota reduced the release of hazardous volatile organic compounds by 70% to 20g/m^2 of paint surface (46).

5.5 Sectors

By far the majority of case studies regarding prevention of hazardous waste come from the automotive sector. This was to be expected, as the amount of hazardous materials used in this sector is significantly higher than in the other sectors investigated in this study (except for the construction sector). An overview of case studies regarding hazardous waste prevention is given in Table 4.

In the construction sector, most case studies identified described the exchange of excavated material, some of which was contaminated and hazardous, with other building sites which used it as aggregates. However, these were only considered as waste prevention if the waste was re-used on the same building site. Two remaining examples are given in Table 5.

Although it was outside the strict scope of this work, it is well known (Defra, EA) that the machine tooling and metal finishing industries are substantial sources of hazardous waste. In addition, the examples in Table 6 show diverse issues associated with other sectors.

Table 4: Prevention of hazardous waste in the automotive sector

Process	Achieved savings by prevention of hazardous waste*	Company	Ref ID
Heavy metals	Complete elimination of Pb, Cd, Hg, Cr(VI) in fork lift trucks	Toyota (global)	(15)
Chemicals / solvents	115 t/yr of solvents	DaimlerChrysler (US)	(37)
	80% of solvents	KD Auto Body (SME, US)	(11)
	24 t/yr	Trimac Transportation (SME, US)	(19)
Painting	75% of purge thinner	NUMMI (US)	(47)
	600 t/yr of purge thinner	Toyota (US)	(25)
Metal forming	22% of hazardous waste	DENSO	(16)
	270 t/yr of cutting oil	SME	(18)
Eco-design	180 t/yr barium-containing chemical waste	Toyota (US)	(25)
Oil Wastes	100 t/yr of oily cutting wastes	b2 Automotive Components	(48)

* *Includes savings from reducing the use of hazardous materials*
Source: Collated by Oakdene Hollins/Brook Lyndhurst

Table 5: Prevention of hazardous waste in the construction sector

Process	Achieved savings by prevention of hazardous waste*	Company	Ref ID
In-situ decontamination	170,000 tonnes	Overview Wales 2005-06	(4)
Re-assessment of hazard	10,750 tonnes	Scott Wilson Ltd, NISP	(13)

Source: Collated by Oakdene Hollins/Brook Lyndhurst
** Includes savings from reducing the use of hazardous materials*

Table 6: Prevention of hazardous waste in the other sectors

Sector	Supported?	Achieved savings by prevention of hazardous waste*	Company	Ref ID
Aerospace:	Envirowise	Clean operations: Reduced paint residue disposals by 170 t/yr through its EMS	BAE Systems	(49)
Pharmaceuticals	Envirowise	Waste minimisation: Reduced methanol use in washouts by 68% saving >£40,000/yr. Over £100,000/yr other savings identified. Clean operations: Also reduced use of xylene in process by 60%saving £17,000/yr, and moved to a reusable IBC system.	Shasun Pharma Solutions Ltd	(50)
Chemicals	Envirowise	Waste minimisation: Hazardous chemical washings are collected and blended into product saving 20 t/yr of hazardous disposals.	Henkel Consumer Adhesives	(51)
Chemicals	Envirowise	Waste minimisation: Used six sigma techniques to optimize cleaning processes to minimize waste, and elsewhere to segregate hazardous wastes. Reduced disposals by £4,000/yr and hazardous wastes by >90%.	Peboc	(52)

Source: Collated by Oakdene Hollins/Brook Lyndhurst

6 What are the Behavioural Issues?

6.1 Motivations

Regulation
The most important reason for reducing hazardous waste seems to be regulatory pressure (53). This is not simply seen in responses to current legal requirements, but also by pre-emptive actions in anticipation of expected future regulations. For example, DaimlerChrysler phased out mercury switches in the US after a corresponding ban had been implemented in Europe (23), as an attempt to avoid reporting requirements (i.e. the US Toxic Release Inventory), and more broadly to reduce business liability due to the perceived legal risks around the disposal of hazardous waste (11).

However, a study of small shop owners showed that even though regulation was able to get them to install required equipment to prevent hazardous waste, there was doubt as to whether compliance was sustained. This was explained by SMEs responding initially to legislation, but lapsing once they realised the low risk of being inspected by law enforcement agents (53).

Cost reduction
Cost reduction is the second most important motivational factor (53). However, it needs be recognised that the high cost of disposing of hazardous waste is dominated by the strict laws regulating it. This not only entails direct handling costs but also the cost of the onerous reporting requirements for hazardous waste shipments (54). There is consequently a strong link between regulatory and cost pressure, and a strong incentive for businesses to substitute less harmful materials for hazardous ones or at least segregate waste types (9).

Again, SMEs often do not consider the cost savings from increase material efficiencies as an incentive for waste prevention. This is believed to be due more to a lack of knowledge of the true cost of waste, than to a genuine lack of potential savings (18).

Customer awareness
Customers can become aware of hazardousness issues through action groups, media attention, third party labelling or by the promotional activities of high performing companies with an interest. Accordingly they may choose to avoid buying products made by certain processes or with material content. An example of this is from the metal finishing industry where a combination of “public opinion, regulatory compliance, and environmental stewardship” is motivating a move from phosphate-based systems to more benign alternatives (55).

Adoption of Environmental Management Systems
There appears to be good evidence that the effort needed to install systems in companies can trigger genuine evaluation of waste and hazard reduction opportunities. Numerous Envirowise case studies are testament to this, including: automotive company b2 Automotive Components (48) which reduced oily wastes by 100 tonnes per year saving £5,500; Henkel Consumer Adhesive (51), which used ISO 14001 to reduce wastes by 20 tonnes per year as well as other process efficiencies; and BAE Systems, also under ISO 14001, reduced paint wastes by 170 tonnes per year (49).

6.2 Barriers

The most important barriers to preventing hazardous waste stated by businesses were found to be (8):

a) technical limitation of production processes
b) cost
c) concerns over product quality.

Additionally, the following barriers were identified from various studies (no ranking):

- low level of enforcement for SMEs
- lack of emphasis on the legislation of waste prevention
- detailed knowledge of specific technical issues
- lack of appropriate knowledge and support.

A general barrier may exist where substantial progress in reducing and substituting hazardous materials has already been made. Many companies appear to have addressed the straightforward opportunities with further gains being more difficult or expensive. This is indicated by a reported falling trend in the number of hazardous material reduction projects initiated or expanded (8).

Generally, the easiest actions relate to organisational actions to improve efficiency. Subsequently, further improvement requires major changes in the raw materials, processes or the products, all of which may exceed the capabilities of existing production processes (technical limitations); may require either high investments or high running costs to modify these (cost); or may lead to a deterioration of the quality of the final product (concerns over product quality).

Every manufacturing company will have a unique set of issues, often highly technically complex. It therefore becomes harder for business support organisation to help companies since idiosyncratic approaches are needed, which requires substantially more effort (8). An analysis of a business support programme in Nebraska (US) showed that simple projects and short-term assistance resulted in the lowest monetary and lowest solid waste reductions per client, whereas in-depth assistance led to the highest savings (35).

Regulatory factors seem to be a motivator not a barrier to waste prevention (8). Some exceptions have been observed for SMEs where legislation may still be partially ignored if no credible enforcement is provided (31). Legislation is generally seen as being more concerned with managing production wastes rather than prevention of waste in the first place. This applies especially to redesign, hazardous material restrictions, recycled content requirements and the apparent lack of emphasis on the development by businesses of innovative product service systems that can sidestep waste (22).

6.3 Enablers

Evidence from some sectors, such as automotive, suggests that even where there is awareness and a willingness to reduce hazardous wastes, the skills and knowledge for doing so do not lie within the company. This is especially a feature of SMEs (36). Where these companies are suppliers to major companies, there are examples of those companies assisting in the diagnosis and improvement of processes. Specialist technical support has been applied but since the problems are of a specific and detailed nature, general business support provision can lack appropriate depth and intensity.

Sector based commitments can provide the necessary motivation and support for change. US examples exist from the metal finishing industry (55), amongst suppliers of hazardous substances (flame retardants,

Deca-BDE, (56)) and more broadly as hazardous waste reduction voluntary commitments such as the Environmental Stewardship Initiative (57). (Similar initiatives can be found in Germany.)

Labelling could be expected to be a motivator of reduction by increasing transparency and awareness, especially when taken in conjunction with standards initiatives. This is the case for EU Ecolabel which specifies maximum levels of detrimental substances either contained within products themselves (such as detergents) or emitted during production (such as finishing agents, mordants, heavy metal dyes in textile manufacture). These levels are generally taken at the leading edge of performance are subject to continual tightening and this might be expected to drive average business performance. Little quantitative evidence exists to date.

7 Conclusions

7.1 Learning

- **Evidence of a high awareness of businesses to the issues around hazardous waste has been found.** This has been mainly fostered by strict regulations and high costs of disposal. Systematic investigations of areas of waste minimisation have become routine for the large generators of hazardous waste (8). Nevertheless, there is also evidence for a significant share of companies not participating, especially among small and medium sized companies.

- **The main route to the prevention of hazardous waste is substitution of hazardous materials by less harmful ones.** This strategy is applied both to hazardous substances contained in the final product, as well as to hazardous materials used as process aids and treatment agents in the production process. Most of these changes have been driven by bans and restrictions on certain substances, additionally fuelled by fear of liabilities or public opinion.

- Additionally many companies try to implement small changes in their processes in order to become more efficient and reduce the amount of hazardous waste being generated. Most of these actions do not involve investment in new equipment, but are organisational involving managerial techniques and training (classic waste minimisation).

- **Legislation has been a powerful driver in reducing the amount of hazardous waste.** It has not only used classic 'command-and-control' instruments, like restrictions and bans, but also installed strong economic incentives by making disposal of hazardous waste onerous and expensive.

7.2 Insights

The achieved reductions in hazardous waste clearly demonstrate the power of regulations in achieving environmental goals. Even if a regulation is enacted in only a single major market it may still force beneficial changes in other areas of the globe. This is shown by the example of mercury in the automotive industry, whose phase-out by some US automotive companies was triggered by bans in Europe. (European vehicle emissions limits similarly force global standards as they form an effective barrier to sale.)

From the waste prevention point of view bans are especially useful, as prohibiting the use of a certain hazardous substance automatically prevents the generation of any associated hazardous waste.

On a policy level, studies have shown the importance of reduction planning and reporting requirements (34). Such requirements do not prescribe companies what to do, but force them to investigate the issues and to develop solutions on their own. Waste audits in a company seem to lead to the identification of 'low-hanging fruit' and significant waste reductions (8), but in order to maximise these reductions, in-depth technical support is required. Consequently, although a broad brush approach to business support may be helpful to initiate hazard identification and audit, it may not be sufficient to help companies progress beyond the simple to more intractable hazards.

Uncertainty stems from the fact that many companies report a reduction of the amounts of hazardous materials being used. A reduction in use of hazardous materials is not equivalent to a reduction in hazardous waste: On the one hand, products made by using hazardous substances may not become hazardous themselves due to sufficient dilution of hazardous components or to chemical transformations rendering the hazardous material harmless. On the other, a small share of highly hazardous material may

render otherwise non-hazardous waste hazardous (e.g. mercury-containing fluorescent lights in general mixed waste). A clearer distinction of these effects in the reporting and analysis of impacts is required.

The role of 'naming and shaming' and public ranking lists of company performance is a powerful tool: Maintaining a positive public image and a low investment risk profile to stakeholders, many companies try to reduce the amount of hazardous waste being produced below the 'significance' level at which they are exempt from reporting. Again such a measure does not prescribe methods to companies, but lets the companies evaluate for themselves the urgency of change and the means appropriate to improve their environmental performance.

As many businesses have been working on hazardous waste issues for some time now, the ability to capitalise on further waste minimisation-type projects seem to have levelled off. Further opportunities will need to be very specific to the actual processes, and probably more expensive. In this context business support becomes difficult. It needs to be capable of delivering in-depth and bespoke solutions, which is often difficult within the remits of the available funding.

A caveat we apply is that much of the evidence is provided by examples from outside the UK. Whilst not highlighted as a research gap, examination of proxies – such as the amount of intellectual property filed – in the UK compared to elsewhere might provide a useful check on whether it is a laggard or a leader in addressing root causes and solutions, if not actual implementation of that research.

7.3 Research Gaps

Two significant research gaps have been identified:

- The **extent of action by SMEs** on hazard reduction could bear further investigation. The majority of evidence located relates to actions of large enterprises.

- The revised Waste Framework Directive of 2008 now includes an additional criterion (H13 - sensitizing) and a re-ordering of the Hazard criteria such that H15 (yields another substance after disposal) is now subject to H14 – ecotoxic. **This may extend the range of hazardous wastes and hence the scope for hazard reduction. This needs to be examined to gain foresight of specific sector impacts.**

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Oakdene Hollins Ltd
Pembroke Court
22-28 Cambridge Street
Aylesbury
Buckinghamshire
HP20 1RS

T: +44(0)1296 423915
E: admin@oakdenehollins.co.uk
www.oakdenehollins.co.uk
www.remanufacturing.org.uk

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