THE LOGISTICS OF MANAGING HAZARDOUS WASTE – A CASE STUDY ANALYSIS IN THE RETAIL SECTOR

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Introduction

Increasing government regulation, coupled with the drive for greater environmental accountability have brought waste logistics to the forefront of supply chain strategies. The retail sector has had to collectively respond to this because of the responsibilities obligated on producers, suppliers and retailers putting products onto the market (Gonzalez-Torre *et al*, 2004). Retailers now have key responsibilities related to the collection, storage, treatment, transportation and disposal of end-of-life materials and packaging waste, as well as the development of customer take-back systems at the store level. At the same time, the use of hazardous materials in servicing retail activities as well as in certain types of consumer products has meant that retailers are also bound to organise critical reverse logistics operations for the safe and efficient collection, storage, transitional treatment, distribution, recycling and final disposal of hazardous wastes. To do this effectively, retailers must develop cost effective strategies to optimise the collection processes and minimise the logistics demand associated with moving hazardous wastes. Collaborative approaches between retailers could bring about benefits in this area.

Through a case study of a dedicated shopping centre, this paper aims to:

- provide insights into the use of hazardous materials as part of typical retail activities,
- investigate the impact of the relevant legislation on the establishment of customer take-back schemes at stores and the development of treatment protocols,
- identify the actors in the associated collection networks and the treatment processes,
- discuss the logistics implications of typical hazardous waste collection practices.

Literature Review

Hazardous materials are prevalent throughout our society. Whilst industry is a primary user of hazardous chemicals, the commercial sector also has a considerable take-up. During 2007 in England and Wales 6.3 million tonnes of hazardous waste were produced from over 200,000 businesses and industry, with 2.4 million tonnes generated as a result of organic chemical processes (37.8%), 0.85 million tonnes by oil and oil water mixtures (13.2%), 0.74 million tonnes as a result of construction and demolition activities (11.2%), 7.2 million tonnes by waste/water treatment and the water industry (11.1%), while municipal and similar commercial wastes accounted for 0.26 million tonnes (4%) (Environment Agency, 2009). Retail outlets and catering units use a range of items containing hazardous substances such as cleaning and maintenance products, fluorescent lighting tubes, batteries and electrical and electronic equipment (EEE) to support their day-to-day operations and customer services. A variety of hazardous waste can be produced and when added to the stream of hazardous end-of-life products returned to stores through customer take-back schemes, a considerable pressure can be placed on retailers to develop distinctly different handling protocols, treatment practices and disposal alternatives. These have to be achieved whilst still maintaining quality in customer services and adding economic value along the supply chain.

The concept that the flow of goods through a supply chain ultimately ends with the consumer is now challenged due to the European Commission's (EC) comprehensive environmental legislation and growing consumer awareness of recycling. Hazardous waste as regulated under the 'Hazardous Waste Directive [91/689/EC]', is defined on the basis of the 'European Waste Catalogue (EWC) 2002' which classifies waste materials under 20 main categories according to how they were produced (650 codes) and in what ways they may be harmful to humans or the environment. Commercial premises have a 'Duty of Care' imposed upon them to make satisfactory arrangements for hazardous waste management, while retailers are obligated under the wider 'Polluter Pays' principle, to set-up and manage material take-back schemes. An increasing number of corresponding regulatory frameworks aim to ensure proper handling and disposal, while shifting waste management to producers to enforce them to re-design products in order to reduce the volume of waste generated and increase the use of recycled materials (Marien 1998).

Hazardous waste management is often complex due to the considerable variation in contractual, business and operational practices that can be adopted in order to meet the considerable legislative requirements (Browne & Allen, 2007). This naturally works against collaborative working in the sector because of the variety of systems that can be used by retailers (Sheu, 2005). The variety in the material characteristics and properties of hazardous waste often dictate specific handling and treatment measures (control and separation) from the principal reverse waste flows to ensure safe, efficient and cost effective collection, transportation, treatment and disposal (Nema & Gupta, 1999; Wang *et al*, 2008).

In order to overcome the operational complexities associated with planning and undertaking hazardous waste collections, many businesses often outsource collection operations to specialised third parties who have the expertise and the tools to offer fully managed services which meet the clients legal obligations. However, in attempting to make waste operations more sustainable, the transport issues become more complicated the more actors become involved (Browne and Allen, 2007). The multiple contract waste management regime that currently exists is symptomatic of the retail industry's apparent failure to drive innovation into the integration and coordination of system's-wide physical flows (collection, storage, testing and inspection, separation, reprocessing and redistribution or final disposal), Pitt (2005), and create co-ordinated and effective reverse logistics strategies. Given the reliance on road movement, it would be advantageous if centralised reverse logistics systems that regulate and integrate hazardous waste management across competing retail supply chains could be established to reduce the transport burden and enhance take-back opportunities.

The complexity of managing hazardous waste has been widely researched in previous studies on reverse logistics which largely focussed on optimising the location and use of treatment facilities in network planning. This was achieved using mathematical models to determine either the type, the locations and the size of treatment and disposal facilities (e.g. Re Velle *et al*, 1991; Koo *et al*, 1991; Stowers & Polekar, 1993; Nema & Gupta, 1999), or the transportation routes from waste sources to specified facilities (e.g. Jennings & Scholars, 1984). The major concern in many studies was minimising private business costs (e.g. Peirce & Davidson, 1982; Hu *et al*, 2002) and transportation and/or disposal risk (e.g. Zografos & Samara, 1990). Researchers have also identified several reverse logistics issues, key to the successful management of hazardous waste, such as the relationships between the integrated functions within the reverse channel (collection, separation, transitional processing and delivery), e.g. Pohlen & Farris, (1992); the interface between inventory control and reverse distribution (Fleischmann *et al*, 1997); the need for a conceptual framework for reverse logistics management (e.g. Carter & Ellram, 1998), and the concept of a reverse supply chain, solely for single product management (e.g. Tsouflas *et al*, 2002). It appears that relatively few theoretical and practical studies have been undertaken investigating cross-supply regarding the management of hazardous wastes produced by different or rival businesses.

Description of the Problem

The design, planning and execution of the logistics networks for waste collection depend on the number and the location of the treatment and disposal facilities, determined by the characteristics of the wastes to be treated, governed by the relevant legislative and operational principles. More complex networks of specialised processing facilities are required when waste falls under one of the European Waste Catalogue categories to minimise the hazards posed. Typical disposition routes for wastes or their component parts include one of the four following alternatives (Prahinski & Kocabasoglu, 2006):

- *Reuse* - which is to reuse or resell the product.
- *Product upgrade* - that is to repackage, repair, refurbish or remanufacture the product.
- *Materials recovery* - which includes recycling and cannibalisation.
- *Waste disposal* - which includes incineration/landfilling the waste product.

This paper focuses on the examination of 4 hazardous wastes, commonly produced by the retail sector to explore the issues determining how the associated reverse logistic operations are undertaken.

Mobile Phones

The mobile phone sector is one of the fastest growing industries in the world (Hanafi *et al*, 2008). In 2008 it was estimated that the mobile penetration in the UK reached over 122% with 74.5 million subscribers. Annual sales of mobiles reached 18 million equating to 75% of the UK population upgrading or replacing their phone every 18 months (NetSize Guide, 2008). To minimise the volume of mobiles ending up in landfill or third world countries, the European Commission introduced the 'Waste Electrical and Electronic Equipment (WEEE) Directive [2002/93/EC]' in 2002, seeking to make producers responsible for financing WEEE collection, treatment and disposal, and to obligate distributors to establish an infrastructure for collecting WEEE in such a way that EEE users have the possibility of returning WEEE free of charge. To this end, customers may drop-off end-of-life electronics in retail outlets either registered with a producer compliance scheme or having in place appropriate arrangements with registered or licensed waste contractors. In addition, customers may be provided with a pre-paid returns envelope to return their phone via the postal network. The method selected is dependent on the size and the hazardous nature of the items to be returned, the size and the available infrastructure of the businesses concerned as well as the cost of the system for individual companies. In a comparison of drop-off and mail-in collection methods, Hanafi *et al*., (2008) concluded that due to the small size of mobile phones, the cost of mailing each product to the transfer/consolidation station was quite high in contrast with the cost of the drop-off method.

Mobile phones consist of a number of modular components having clear potential to be remanufactured and reused. Metal contents from batteries can be sent for recycling, plastic elements can be recovered through energy-from-incineration, while some plastics recovered from the outer body of recycled telephones can be granulated, reformed and reused in mouldings such as car wheel trims. In addition, a number of other useful parts including aerials, battery connectors, printed circuit boards (PCBs), connectors including gold-coated edge contacts on PCBs, integrated circuits (ICs), keyboards, lenses, microphones, phone housings and speakers can also be recovered and re-used (Envocare, 2009). With increasing numbers of stops/collections on each part of the take-back journey increases the risk of valuable untreated waste components being illegally extracted or stolen (Chan & Chan, 2008). As a large proportion of manufacturing activities for mobile phones have moved to China with direct impacts on forward logistic costs, it is important to design effective reverse logistics that incorporate remanufacturing, reselling and repackage activities to recover assets and add extra value.

Waste Cooking Oil

Waste cooking oil from catering premises must be correctly managed as it cannot be poured down drains or sewers because of issues related to blockages, odours or vermin. It is estimated that in the UK, more than 10,000 tonnes of used cooking oil are produced every week and there are approximately 200,000 sewer blockages and pollution incidents throughout England and Wales every year, 75% of which are directly related to deposits caused by fat, oils and grease (Water.org, 2009). According to the 'Animal By-Products Regulation – Guidance on Cooking Oil [2002/2774/EC]', proper storage and collection must be made by authorised waste contractors. To reduce dependency upon landfill sites, the European Commission strongly supports the recovery of waste oil, and waste collectors are expected to supply it to either producers of bio-diesel to power vehicles, incinerators to generate electricity or the chemical industry.

Clinical Waste

Certain types of waste produced as a consequence of health care activities in hospitals and community settings, including retail outlets that also operate as surgeries running eye operations (such as laser eye surgery treatments), are hazardous and can therefore pose a danger to the environment and human health. Infectious wastes (such as anatomical waste and sharps), cytotoxic and cytostatic medicines and healthcare chemicals must be properly segregated, stored in secure areas and packaged and labelled properly prior to being collected by registered clinical waste contractors in accordance with several pieces of legislation including the 'Health and Safety' regulations and the 'Duty of Care'. Dependent on waste's characteristics, the treatment options differ. Cytotoxic and pharmaceutical wastes must be incinerated before disposal to landfill, while human body parts must be either incinerated or treated by chemical disinfection processes followed by shredding prior to being disposed in landfill in order to render the clinical and healthcare wastes safe. All these processes can involve additional transport and specialist contractors.

Fluorescent Lighting Tubes

With the move towards greater energy efficiency, a number of major UK retailers and energy suppliers have led a voluntary initiative to phase out traditional light bulbs from the domestic market by 2011. Currently, over 100 million fluorescent light tubes are scrapped annually, leading to approximately 20,000 tonnes of mercury and lead contaminated glass going to landfill. Of the 100 million tubes, only 12 million are recycled (Phs, 2009). Under the 'Hazardous Waste Directive [91/689/EC]', light tubes are considered as hazardous waste and are legislated under the 'WEEE' and the 'Restriction of Use of Certain Hazardous Substances (RoHS) [95/2002/EC]' Directives, prohibiting their disposal in landfill due to the high levels of heavy metals, particularly mercury. Retailers are allowed to sell lighting equipment that meets certain technical specifications and bears the 'CE' marking under the demands of the 'Energy Efficiency Requirements for Fluorescent Lighting Directive [2000/55/EC]'. They must also take all appropriate measures to collect, store and dispose of end-of-life fluorescent lighting tubes separately from the general waste to enable proper disposal. Collection of fluorescent lighting tubes from retail outlets and catering units must be made by registered waste contractors, while tubes may be disposed of at properly authorised disposal sites. New technologies offer the opportunity to recycle all the components of a tube (glass, phosphor, mercury and metal end caps) in appropriate recovery sites.

Case Study

To assess the impact of the current legislative and operational pressures on the organisation of hazardous waste management systems and the formulation of reverse logistics networks, these four hazardous waste types were investigated across a number of retail outlets in a dedicated shopping centre in Hampshire. The centre incorporated 2 department stores, 20 catering units and another 74 retail outlets selling a variety of goods including clothing, footwear, electrical products, jewellery, games, sports goods, books and optical goods. As part of the standard tenant contract, retailers were committed to maximise recycling and develop long-term waste minimisation strategies. The 2 department stores and another retail outlet had developed in-house waste collection mechanisms while 93 businesses had joined a centrally coordinated waste collection and disposal service for recyclable materials including cardboard, polythene, glass, paper, coat hangers, pallets, cages/scrap metal, fluorescent lighting tubes and wood. In 2008, a total of 434 tonnes of recyclate was consolidated centrally and sent for further processing by 6 main waste contractors employed by the landlord of the shopping centre.

A number of retailers also produced hazardous wastes such as WEEE, batteries, clinical waste, fluorescent lighting tubes and used cooking oil, being either back-loaded to head offices, centralised distribution centres or other process/treatment plants. This was done using in-house collection systems, predominantly business specific, using in-house fleets or outsourced collections via third-party logistics providers or specialised waste contractors.

Data collection

Hazardous waste operations were quantified as part of a wider data collection exercise researching the forward and reverse logistics activities used by businesses in the centre for core goods, product returns and waste/recyclate. A two-stage interview process was adopted including face-to-face contacts with the managers of the retail outlets and catering units operating in the shopping complex followed by phone interviews with key actors including third-party logistics providers, waste contractors and recyclers dealing with the collection, transport, treatment, recovery or disposal of hazardous wastes. In addition, further information about the processes used by the retail companies, the logistics providers and the waste contractors was gathered from on-line sources.

The first survey stage employed a structured interview, incorporating qualitative and quantitative questions based on other recent urban freight survey methodologies (DfT, 2008; MIRACLES, 2006) to research the treatment/handling practices developed on-site by individual businesses, the capacity of the systems in place (labour, equipment, storage space), the hazardous waste arisings, product testing 'gate-keeper' issues, collection contracts and origin-destination data for the associated outbound logistics activities. During the first survey stage, a 96% response rate was achieved eliciting detailed responses from 92 retail outlets in the shopping centre.

Results

Respondent businesses were classified under the 'UK Standard Industrial Classification of Economic Activities 2007' code. Based upon this classification, the results suggested that the principal producers of hazardous wastes were 16 catering units and other stores selling electronics, cosmetics and jewellery. In addition, 10 stores produced waste batteries however in 6 cases these were managed along with the general WEEE stream. In 2 cases, systems had been set up to post used batteries back to distribution centres and in another 2 cases they were disposed of by staff in public recycling points. The vast majority of retailers (95%) used fluorescent tubes for lightning purposes (Table 1).

Business Type	Total No of Stores	Hazardous Waste	No of Producing Stores	Back-loading	Waste Contractor	Central Collection
Electronics	7	WEEE	7	2	5	-
Jewellery	8	WEEE	3	1	2	-
Games/Toys	3	WEEE	1	1	-	-
Catering Units	20	Waste Cooking Oil	3	1	2	-
Optical Goods	3	Clinical Waste	1	-	1	-
All Businesses	92	Fluorescent Lighting Tubes	87	1	71	15

Table 1: Hazardous waste production by retail outlets and catering units in the shopping centre.

It was estimated that during a typical week (non-peak sales season) retailers produced 8 plastic totes filled with WEEE and batteries (634 litres), 3 yellow/orange sacks with clinical waste (152 litres) and another 3 containers with used cooking oil (90 litres). It was estimated that respondents produced approximately 725,000 litres of waste weekly (31.37% general mixed waste, 4.8% mixed paper, 56% cardboard, 7.7% polythene and plastic, 0.1% WEEE and batteries, 0.02% medical waste and 0.01% used cooking oil). With regard to hazardous waste collections, the study identified 65 specialist waste contractors visiting the complex on a dedicated or, 'on-request' basis. The vast majority of these (n=59) were electrical/maintenance companies replacing and collecting end-of-life fluorescent tubes during routine maintenance visits a few times a year. Another 2 specialist waste contractors collected waste cooking oil on fixed weekly and monthly appointments, whilst clinical waste was collected by different specialist collectors on a dedicated weekly basis with 3 specialists collecting WEEE on a similar basis. Out of the 7 businesses selling a variety of electronic products including computers, printers, television sets and game consoles, only 5 stores were selling mobile phones. Under the WEEE Directive these 5 stores were obligated to develop customer take-back schemes. It was found that 4 stores employed the same waste contractor to collect WEEE, while in one case waste was back-loaded using in-house fleet.

Mobile Phones

Contractor A was used by 4 retailers in the centre and currently processes over 250.000 phones a month across its network with approximately 80% being refurbished. Contractor A is the only company in the UK to be granted four key licenses under the WEEE legislation, being a licensed operator under the Producer Compliance Scheme, an approved authorised treatment facility and a designated collection facility and approved exporter. Their system allows customers to drop their unwanted handsets into retail outlets directly, or use the freepost service as the first stage in the take-back operation. A limited-size, in-house fleet of vans is available across Contractor A's national operation, but are not normally used for waste collections, therefore a third-party logistics provider's fleet is employed when collections are internally organised. Collections made 'on-request' are processed through Contractor A's service team, however, local collection schedules are organised by the logistics provider on the day prior to collection.

Two stores in the shopping centre provided their customers with pre-paid envelopes to ship mobiles to Contractor A's processing hub located in Essex, another received Contractor A's collections whenever requested, while the latter used third-party delivery vehicles to backload handsets. Mobile phones collected either by Contractor A or by the third-party contractor were initially transported to two depots (6.05 and 5.5 miles correspondingly) located in Southampton (Southampton Depots A and B) where handsets were consolidated prior to being sent to the main processing hub located in Essex (113 miles), Figure 1. There, handsets under-go 'pre-procession' which includes pre-segregation (separation of the handset, charger and battery), scanning and checks with police for blacklisting (for lost or stolen mobiles). Phones suitable for reuse are tested, repaired and/or refurbished according to the manufacturer's instructions, data cleansed, repackaged and shipped directly from the processing hub in Essex to UK customers or to developing countries. Phones not fit for reuse are sent to a specialist recycling agent in Sweden where metals are extracted using incineration, batteries are sent to a specialist recycler in France to extract hazardous substances (cadmium, nickel, lithium ion/polymer and nickel metal hydride) before being returned to productive use. Metals and plastic from chargers and accessories are recovered and recycled (melted) respectively, the latter being used to make plastic sheeting.

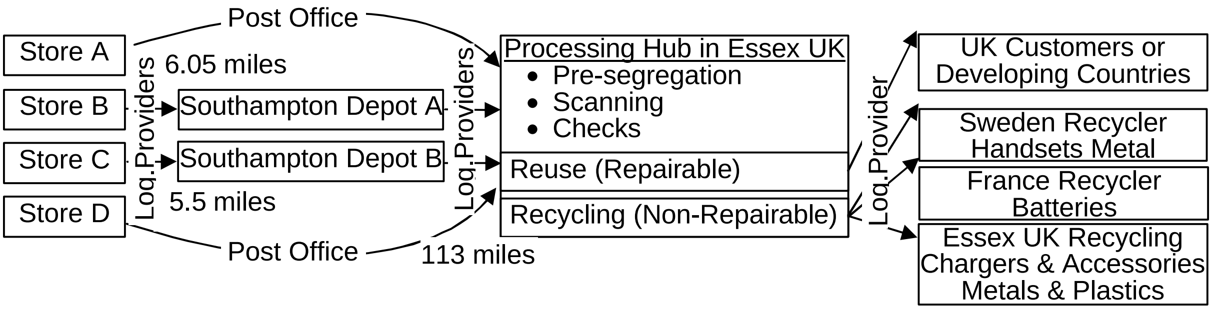

Figure 1: Flow diagram showing the different handling stages for mobiles collected by Contactor A.

Waste Cooking Oil

Contractor B is a nationwide company with more than 15 UK oil collection points and 3 purpose built depots, making it the largest vegetable oil management business in the country. Contractor B is fully licensed and insured as a waste contractor and carrier, while it manages the cooking oil cycle for a wide range of catering establishments from restaurants, to pub chains, hospitals and schools. Customers may return used cooking oil in its original container as long as it meets duty-of-care requirements, or they may use blue containers ranging from 15 to 1000 litres supplied by the contractor. Collections are made on a weekly, fortnightly or monthly basis by Contractor B's own fleet of vans.

The retailer-survey identified one restaurant being serviced by Contractor B. During the fixed weekly visit, empty 50 litres blue bins were delivered in order to replace the full drums. Used cooking oil from the restaurant along with oil collected by other local restaurants and pubs was transferred to the main purpose-built depot in Norfolk (200 miles) where it is heated, cleaned and then filtered before being transferred to a processing plant in Middlewich Cheshire (177 miles) for conversion to bio-diesel (Figure 2). All packaging items including cardboard and tins are recycled, while biodiesel is sold to several companies across the UK.

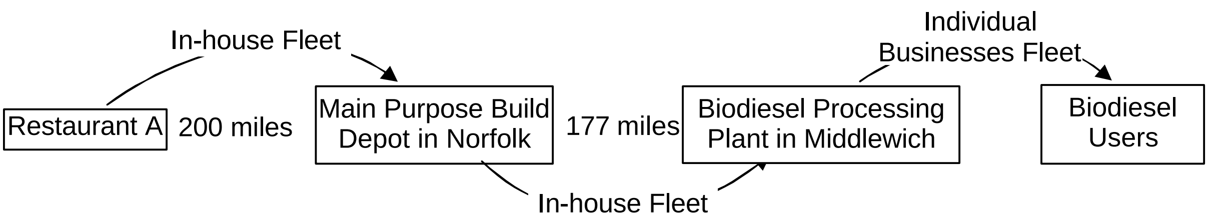

Figure 2: Flow diagram showing the different handling stages for used cooking oil collected by Contactor B.

Fluorescent Lighting Tubes

Contractor C is a global specialist in designing and manufacturing retail lighting. In addition, Contractor C offers maintenance and collection services for end-of-life tubes. Lamps being replaced by retailers must be placed in the original or other specialist packaging and be safely stored in order to be collected during the subsequent maintenance visit.

The surveys identified that one retail outlet operating in the shopping centre had a maintenance contract in place with lamps manufacturer Contractor C who visited the shopping complex on-request basis. Using their in-house vehicle fleet, spent lamps are collected and moved to the lamps factory in Wiltshire (72 miles) where they are placed in containers and stored. When containers are filled, another Contractor F who is a specialist in lighting equipment with its own compliance scheme, collects the containers and moves them using its own fleet to a process/recycling plant in Manchester (174 miles). Capacitors and batteries which can be present in the tubes (e.g. in emergency lighting systems) are separated in order to remove the hazardous substances. The tubes are crushed in a shredder and the glass recovered, while the mercury contaminated phosphor powder is distilled to produce pure mercury for reuse. Metals and glass are put back into the market with metals often being exported to the Far East (Figure 3).

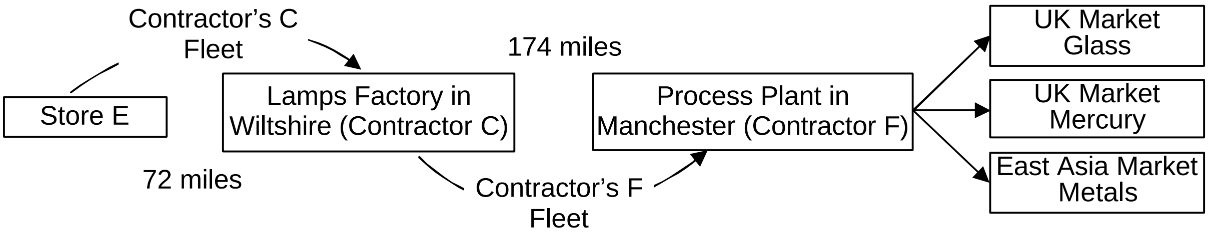

Figure 3: Flow diagram showing the different handling stages for fluorescent lighting tubes collected by Contactors C and F.

Clinical Waste

Contractor D operates in the area of clinical waste disposal, offering a range of removal processes to businesses. Dependent on the clinical waste type (e.g. sharps, cytotoxic and cytotaxic waste), safe disposal is ensured through proper packaging and colour coding. Contractor D is a registered and licensed waste carrier using a Sub-Contractor's (E) purpose-built vehicles. The study identified that Contractor D collects clinical waste produced as a result of laser eye surgery treatments run in a store selling optical equipment. In addition, other clinical wastes such as sharps and expired drugs are collected from this store. As soon as waste is collected it is placed onto one of sub-contractor E's medical services vehicles, it is segregated and transported to the businesses licensed waste transfer depot in Middlesex (85 miles) via the sub-contractor's local depot (Southampton Depot E) (15 miles). Clinical waste is then transferred into large secure containers identifiable by bar codes and is sent to treatment of incineration (Figure 4).

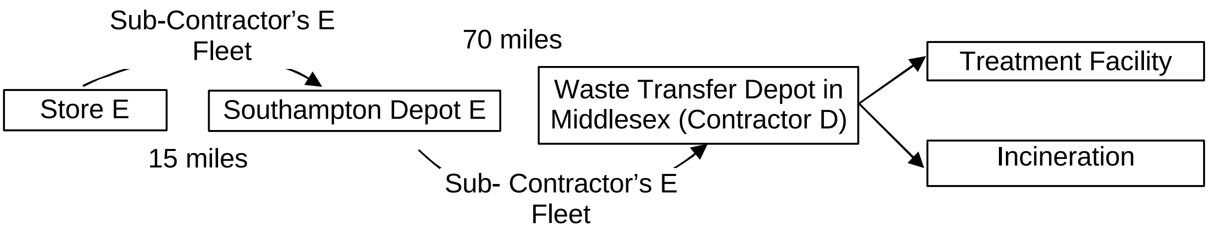

Figure 4: Flow diagram showing the different handling stages for clinical waste collected by Contactor D using Sub-Contractor's E fleet.

Conclusions

The case studies of hazardous waste management practices adopted by retailers in a dedicated shopping centre demonstrate the complex nature of the interactions existing between the many players involved. The transport associated with its movement is largely dictated by the characteristics of the waste and the legislation governing its handling, treatment and disposal, with many specialist contractors providing fully managed services to retailers which meet the producer responsibility requirements. Within a retail setting, there could be considerable benefits from co-ordinating hazardous waste take-back where competing retailers can identify common waste categories that require managed return and processing. This can only be realistically achieved through a third party controller, as in the 'landlord-tenant' arrangement prevalent in most dedicated shopping centres. This body would oversee the waste output from the centre and would co-ordinate take-back of the consolidated waste streams through specific channels, so reducing the amount of separate contractor activity. This same theory could be applied to retailers on a city high street if such a third-party controller could be identified and allowed access to the waste inventories of the individual retailers. The real challenge would lie in ensuring effective 'gate-keeping' activities at source, to guarantee the separation of potential waste contaminants and whether this could be done effectively before different retailer loads were combined. Local authorities could be best placed to act in this role and create waste 'service plans' to serve retailers in an urban setting, to reduce waste service vehicle impacts.

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