Material change for a better environment

Environment Agency

Waste Protocols Project

Tyre-derived rubber materials

A technical report on the manufacture of tyre-derived rubber materials

Contents

Executive summary

Background

The Business Resource Efficiency and Waste (BREW) Waste Protocols Project aims to provide guidance on various waste streams that will:

- define the point of full recovery from a waste back into a product or material that can be reused by the business or industry, or sold into other markets; or
- confirm to the business community what legal obligations remain to control the reuse of the treated waste material.

The Environment Agency currently considers that all tyre-derived rubber materials remain waste until the point at which they are fully recovered through application in a final product. The Project Board asked a Technical Advisory Group (TAG) to consider the feasibility of producing a Quality Protocol that would enable the point of recovery of tyre-derived rubber materials to be moved closer to the point of production. The TAG was asked to consider the potential for using the British Standards Institution Publicly Available Specification BS PAS 107: 2007 (PAS 107) for producing tyre-derived rubber materials as part of the Quality Protocol.

Methodology

The TAG brought together representatives from the Environment Agency, the Waste & Resources Action Programme (WRAP) and industry. Its remit was to produce a technical report setting out the process and controls necessary to consider at which point tyre-derived rubber materials cease to be waste. In doing so the TAG:

- identified and quantified the major markets and appropriate end uses for tyre-derived rubber materials;
- identified the current legislative framework that governs the production, handling, storage, transportation and use of tyre-derived rubber materials;
- identified and quantified (subjectively from a wide range of research documents) the relative risk to human health and the environment from the use of tyre-derived rubber materials in each individual market, namely:
  - civil engineering (non-road) applications;
  - civil engineering (road) applications;
  - sports, leisure and safety surfaces applications; and
  - consumer/industrial applications; and
- proposed appropriate mitigation measures and routes forward for each of the major markets such that certain end uses may be regarded as fully recovered when strictly defined conditions are met.

Findings

The TAG's findings are summarised below.

- The assessment was limited to the production of tyre-derived rubber materials from used tyres using ambient and cryogenic processing techniques.
- A sustainable market exists in the UK for tyre-derived rubber materials. Material produced to the specifications contained within PAS 107 has 'certainty of use'.
- The regulatory controls that currently apply to the processing, storage and use of tyre-derived rubber materials are the Environmental Protection Act 1990, Waste Management Licensing Regulations 1994 (as amended), Environmental Protection (Duty of Care) Regulations 1991 (as amended) and Water Resources Act 1991.
- The EU Registration, Evaluation, Authorisation and Restriction of Chemical substances (REACH) Regulation 2006 has the potential to apply to tyre-derived rubber materials should a Quality Protocol be endorsed and the material no longer be defined as a waste. The TAG did not assess fully the volume and complexity of work required to meet the requirements of the REACH Regulation. However, this new legislation could affect UK manufacturers of tyre-derived rubber materials.
- There are uncertainties surrounding the outcome of ongoing work at a European level by the European Tyre & Rubber Manufacturers Association (ETRMA) and other key organisations to reclassify tyre-derived rubber materials as a non-waste under the current review of the Waste Framework Directive.
- The processing operations associated with production of tyre-derived rubber materials to meet the requirements of PAS 107 are outlined in Section 4 of this technical report. Tyre-derived rubber materials manufactured from used tyres can meet the quality specifications defined in Section 6 of this report and require no further processing prior to use.

- At present, there is no single organisation that could effectively administer an independent material verification and certification scheme on behalf of all manufacturers of tyre-derived rubber materials. Thus there is an unquantified risk surrounding the lack of a suitable mechanism (which could be in place with publication of a Quality Protocol) to verify a manufacturer's claim that their operations are in accordance with the Quality Protocol.
- It is possible that the use of tyre-derived rubber materials in certain applications could lead to a negative environmental impact in some aquatic receptors. Measures to mitigate these risks were agreed (see Section 8 of the report).
- On the basis of the risk assessment outlined in Section 8 and provided the recommended mitigation measures are adopted, the risks of the identified hazards from the use of tyre-derived rubber materials are considered to be low in the following applications:
  - landfill engineering;
  - civil engineering (non-road) applications;
  - civil engineering (road) applications;
  - sports, leisure and safety surfaces applications; and
  - consumer/industrial applications.

Recommendations

The TAG recommended that:

- a Quality Protocol be developed for tyre-derived rubber materials based on the findings of this technical report;
- the uncertainty surrounding the implications of REACH and current activity at a European level should be raised at the consultation stage and wider industry views sought; and
- the identification of an independent body to administer an accreditation and certification scheme for UK manufacturers of tyre-derived rubber materials against a Quality Protocol should be raised as a consultation question to elicit responses from industry and other stakeholders.

In addition to developing a Quality Protocol, the TAG recommended that:

- the results of testing tyre-derived rubber materials against German DIN standards are reviewed with a view to assessing their potential use as an industry benchmark which could be incorporated into the Quality Protocol at a later date; and
- cryogenic processing is added to the scope of PAS 107 at the next PAS review.

Since this technical report was signed off by the TAG, the Environment Agency has recommended that the Quality Protocol should include:

- washing or weathering of the tyre-derived materials as a requirement to enable tyre-derived rubber materials to cease to be waste; and
- the time length for weathering should be 30 days but wider industry should be asked for their views on this at consultation.

1. Introduction

1.1 The Waste Protocols Project is a joint Environment Agency and Waste & Resources Action Programme (WRAP) initiative, funded by the Department for Environment Food and Rural Affairs (Defra) Business Resource Efficiency and Waste (BREW) Programme.

1.2 Uncertainty over the point at which 'waste' is fully recovered and ceases to be waste has meant that some materials have continued to be controlled under the EU Waste Framework Directive and, in some cases, disposed of to landfill. To provide more certainty, to stop materials being landfilled unnecessarily and to increase the use of waste as a resource, we have set up the Waste Protocols Project.

1.3 Depending on the circumstances of the sector concerned, the project seeks to achieve one of the following outcomes:

- to produce a Quality Protocol defining the point at which waste may become a non-waste product or material that can be either reused by business or industry, or supplied into other markets, enabling recovered products to be used without the need for waste regulation controls; or
- to produce a statement that confirms to the business community what legal obligations they must comply with to use the treated waste material.

1.4 Tyre-derived rubber materials are one of the waste streams addressed by the BREW Waste Protocols Project. A Technical Advisory Group (TAG) was set up to bring together representatives from the Environment Agency, WRAP and industry. Appendix A is a list of TAG members and Appendix B gives the TAG's terms of reference.

1.5 The Waste Protocols Project Advisory Board asked the TAG to consider the feasibility of producing a Quality Protocol that would enable the point of recovery of tyre-derived rubber materials to be moved closer to the point of production. In particular, the TAG was asked to consider the potential for using the British Standards Institution Publicly Available Specification BS PAS 107: 2007 (PAS 107) for producing tyre-derived rubber materials as part of the Quality Protocol.

1.6 In order for tyre-derived rubber materials to be considered as having ceased to be waste, it is necessary to demonstrate that:

- the material has been fully recovered; and
- there is no further need for waste regulatory controls.

1.7 Therefore, the TAG looked at a number of issues considered of particular relevance, such as to find the point where the waste:

- has a market and therefore certainty of use;
- presents the same or lower risk as a virgin material to human health and the environment; and
- meets a standard/specification and requires no further processing.

1.8 Used tyres may be sold as 'part-worn' tyres for reuse. These are not classed as a waste but as second hand goods, because they are simply being re-marketed in their existing state for their original use. However, when used tyres reach the end of their life, they will be considered to be waste. This report deals with such waste.

1.9 This technical report focuses on the reduction in size of used rubber tyres using ambient and cryogenic (freezing) production techniques. These techniques are defined in Appendix D and section 4. Table 1.1 overleaf shows how, for clarification, tyre-derived rubber materials have been interpreted for the purposes of the technical report.

1 See http://ec.europa.eu/environment/waste/legislation/a.htm

Table 1.1 Size categories of tyre-derived rubber materials	
Rubber shred	Size-reduced rubber to a maximum of 300mm
Rubber chips	Size-reduced rubber to a maximum of 50mm
Rubber granulate	Size-reduced rubber to a maximum of 10mm
Rubber powder	Size-reduced rubber to a maximum of 1mm
Fine rubber powder	Size-reduced rubber to a maximum of 0.5mm

1.10 This document reports on the TAG's progress on this topic and provides recommendations to the Waste Protocols Project Advisory Board on certain specific issues. As part of the technical report development, the TAG:

- identified and quantified the major markets and appropriate end uses for tyre-derived rubber materials;
- identified the current legislative framework that governs the production, handling, storage, transportation and use of tyre-derived rubber materials; and
- identified and quantified (subjectively from a wide range of research documents) the relative risk to human health and the environment from the use of tyre-derived rubber materials in each individual market, namely:
  - landfill engineering;[2]
  - civil engineering (non-road) applications;
  - civil engineering (road) applications;
  - sports, leisure and safety surfaces applications; and
  - consumer/industrial applications.

1.11 The following are not covered by this technical report, and therefore still remain under the current waste regulatory control:

- the use of whole tyres for landfill or coastal erosion applications;
- the use of whole or partially size-reduced tyre-derived rubber materials for use as an alternative fuel source (e.g. cement kilns);
- the thermal treatment of used tyres to recover constituent compounds (e.g. pyrolysis or microwave); and
- the application of unbound tyre-derived rubber materials on agricultural land.

1.12 Current markets for tyre-derived rubber materials are described in more detail in Section 2 and Appendix C. The tyre-derived rubber materials market in the UK is an emerging one and many applications may arise in the future that are not covered by this report. This report is not intended to constrain the applications of tyre-derived rubber materials but to ensure consistent standards for processing and use.

1.13 This report gives the TAG's views on whether, and at which point, waste regulation controls can fall away. The Environment Agency currently takes the view that tyre-derived rubber materials do not cease to be waste until they have been:

- processed in accordance with the specifications detailed within this report to produce a saleable product as described in Table 1; and
- incorporated into a product or function and applied in one of the applicable market sectors detailed in paragraph 1.11.

2 The activity of 'recovery of shredded waste tyres for use in underground construction works including drainage and insulation' is currently covered by the Environment Agency's low risk regulatory policy and therefore a waste management licence is not required for this activity.

2. Key markets for tyre-derived rubber materials

2.1 The following were suggested by a market analysis (see Appendix C) as important markets for tyre-derived rubber materials prepared according to PAS 107:

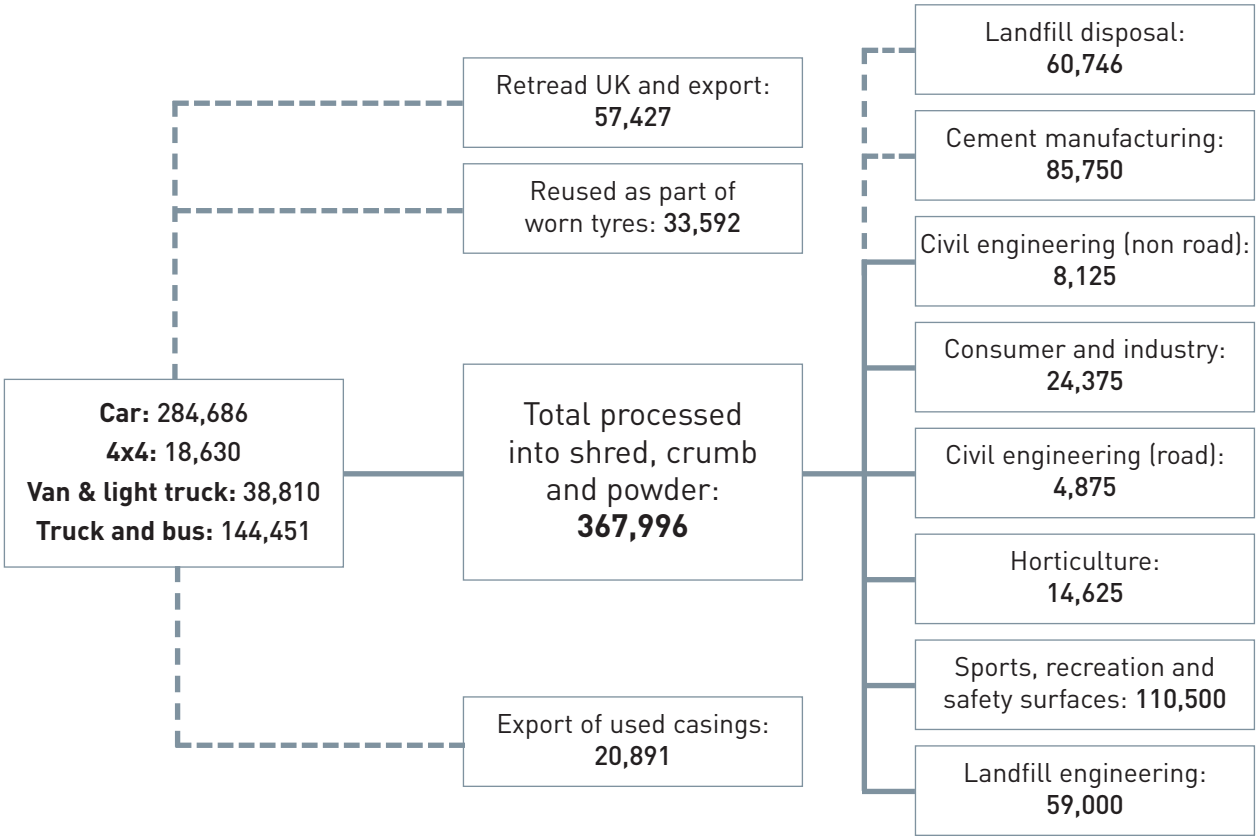
- landfill engineering (drainage and stabilisation);
- civil engineering (non-road) applications;
- civil engineering (road) applications;
- consumer/industrial applications; and
- recreational and leisure applications (including sports and safety surfaces).

2.2 Figures gathered by the then Department of Trade and Industry (now BERR) indicate that the majority (71 per cent) of the 486,578 tonnes of used tyres in 2005 arose from replacement tyre sales (344,839). Some 33 per cent is understood to have been used to produce tyre-derived rubber materials in 2005, accounting for 162,500 tonnes of used tyres. This figure excludes shred going to landfill engineering.

2.3 Figure 2.1 shows the quantities going to different end markets in 2005. However, the situation has changed significantly since then because disposal of shred to landfill has been banned since 2006.[3] More recent figures were not available at the time of writing. There have been significant increases in the amount used for landfill engineering as a consequence of the ban[4] and the most significant markets in the UK are now landfilling engineering and the sports, leisure and safety surfacing industries.

2.4 Oakdene Hollins Ltd has estimated the combined market value of the uses of tyre-derived rubber materials to be £22 million per year.[5]

Figure 2.1 Main markets for processed used tyres, 2005 (tonnes)



Source: DTI (now BERR) used tyre statistics 2005 and WRAP (2006a).
Note: The tonnages sold to end applications are before steel and fibre were removed. They are an over-estimate of the tonnages of shred used in some applications because they do not take account of the removal of steel and fibre.

3 EU Landfill Directive 99/31/EC banned the landfilling of whole tyres from 2003 and shredded tyres from 2006 (see http://ec.europa.eu/environment/waste/landfill_index.htm).
4 E-mail communication with WRAP.
5 E-mail contact with Oakdene Hollins. Ltd.

3. Current legislative position

3.1 There is currently no legislation in the UK that relates specifically to the processing of used tyres into crumb and shred. However, a number of regulations relating to the activities of waste handling, storage and processing are relevant to processors of used tyres.

3.2 Table 3.1 summarises the provisions governing the collection and storage of used tyres for secondary processing into crumb and shred.

Table 3.1 Legislation governing the collection and storage of used tyres for secondary processing into crumb and shred

Legislation	Relevant provisions
Environmental Protection Act 1990	These relate to the handling or disposal of waste. For example, a waste management licence is needed to deposit, treat, keep or dispose of waste unless the activity is exempt. There are offences relating to waste activities that are likely to cause harm to human health or pollution of the environment.
Environmental Protection (Duty of Care) Regulations 1991 (as amended)	Duties placed on the holder of waste to ensure that, when transferred and transported, the waste is properly handled. Waste transfer notes must be completed and waste carriers must be registered with the Environment Agency (in England and Wales).
Waste Management Licensing Regulations 1994 (as amended)	Various provisions concerning waste management licences.* Schedule 3 lists applicable exemptions.
Water Resources Act 1991	It is an offence to cause or permit pollution of controlled waters under this Act.

* See http://www.environment-agency.gov.uk/subjects/waste/1416460/ for details of the waste management licensing regime in England and Wales.

3.3 Waste tyres must be collected and transferred to reprocessors only by a registered waste carrier, i.e. a haulier who has registered with the Environment Agency, Scottish Environment Protection Agency (SEPA) or the Environment and Heritage Service in Northern Ireland.

3.4 Although the Environment Agency has taken a low risk regulatory position in relation to the activity of storing shredded tyres destined for recovery, sites processing used tyres into rubber crumb, shred and powder still need a waste management licence (WML).

3.5 Table 3.2 summarises relevant legislative controls.

Table 3.2 Summary of current legislative controls on the transportation of used tyres, processing of tyre-derived rubber materials and the delivery/receipt of final product once it has left the reprocessing site

Activity	Current legislative control	Current approach
Delivery of whole and/or cut used tyres for production of crumb and shred	Used tyres delivered for processing are considered to be waste and they must be handled according to the Duty of Care laid down by the Environmental Protection Act 1990 and the Environmental Protection (Duty of Care) Regulations 1991 (as amended). The tyres must be transported by a person who is registered as a waste carrier.	Normal regulatory controls apply.

continued

Table 3.2 Summary of current legislative controls on the transportation of used tyres, processing of tyre-derived rubber materials and the delivery/receipt of final product... cont.

Activity	Current legislative control	Current approach
Storage of shredded used tyres destined for recovery	The storage requires a waste management licence under the Environmental Protection Act 1990.	The Environment Agency has adopted a low risk regulatory position* on the storage of shredded used tyres. The storage must be secure.† No such low risk position applies in Scotland or Northern Ireland, where normal regulatory controls apply.
Processing of waste tyres into clean and rough rubber materials in accordance with the defined specifications within PAS 107	The treatment of waste requires a waste management licence under the Environmental Protection Act 1990.	Normal regulatory controls apply
Processing of waste tyres into rubber granulate and powders in accordance with the defined specifications within PAS 107	The treatment of waste requires a waste management licence under the Environmental Protection Act 1990.	Normal regulatory controls apply.
Delivery of tyre-derived rubber materials to end user (consumer)	Tyre-derived rubber materials are currently viewed as waste and they must be handled according to the Duty of Care laid down in the Environmental Protection Act 1990 and the Environmental Protection (Duty of Care) Regulations 1991 (as amended). The materials must be transported by a registered waste carrier.	Normal regulatory controls apply until such time as the tyre-derived materials are re-incorporated into their final use product/application.
Use of tyre-derived rubber materials by the end user (consumer)	Tyre-derived rubber materials are currently viewed as waste and their use requires a waste management licence under the Environmental Protection Act 1990 unless the activity is exempt from licensing under the Waste Management Licensing Regulations 1994 (as amended).	The Environment Agency has set out a low risk regulatory position* on the use of shredded tyres for construction applications (including drainage and insulation). No such low risk position applies in Scotland or Northern Ireland, where normal regulatory controls apply.

* Appendix A of Environment Agency Guidance on Low Risk Waste Activities (http://www.environment-agency.gov.uk/commondata/acrobat/app_a_v15_1098102.pdf).

† The definition of secure is that waste must be kept in a suitable container, building or place and that all reasonable precautions must have been taken to prevent the waste escaping or members of the public accessing that waste.

3.6 REACH Regulation

3.6.1 The REACH Regulation[6] does not normally apply to waste as there is a specific exemption for waste[7] contained within Title I, Article 2(2). However, if a point is found where tyre-derived rubber material, processed to specific requirements, can be classified as a product, the tyre-derived rubber material is no longer a waste and it is possible the REACH Regulation could apply.

3.6.2 The UK Competent Authority on REACH [Health and Safety Executive (HSE)] and the Department for Environment, Food and Rural Affairs (Defra) were consulted as part of the development of this technical report. Their view was that, should tyre-derived rubber materials be reclassified as a product and not a waste, there exists the potential for them to fall under the definition of a 'preparation'.[8]

3.6.3 Should tyre-derived rubber materials fall under the REACH Regulation, manufacturers of such materials would be required to register under Article 6 of the Regulation. This registration would require them to submit a technical dossier to the European Chemicals Agency containing the information required by Article 10(a)(b). Where tonnages exceed 10 tonnes per year, a chemical safety report would also be required (Article 14).

3.6.4 Annex XIV of the REACH Regulation will contain a list of chemicals of high concern to the European Chemicals Agency. At the time of writing, this list has yet to be officially agreed, although it is commonly thought that certain substances (i.e. those on existing lists such as Dangerous Substances Directive or Water Framework Directive Priority Lists) will also be included in Annex XIV.

3.6.5 These lists include polyaromatic hydrocarbons (PAHs) and nonylphenols – both of which are present, albeit in small quantities, in used tyres. This would have the added complication that, if tyre-derived rubber materials were included within the scope of REACH, testing would be required to ascertain whether or not the concentrations of these substances were present above the threshold quantities set out in the REACH Regulation (Articles 56–59). This would apply regardless of whether or not tyre-derived rubber materials were classified as a 'preparation' or an 'article'. If threshold values are exceeded, there is a requirement to produce an authorisation and chemical substitution plan.

6 Regulation (EC) No. 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). See http://ec.europa.eu/enterprise/reach/index_en.htm for more information.

7 As defined by the Waste Framework Directive 2006/12/EC.

8 The term 'preparation' is defined in Article 3(2) of the REACH Regulation as being 'a mixture or solution composed of two or more substances'.

4. Process description

4.1 The scope of this technical report is tyre-derived rubber materials manufactured from used tyres using either ambient or cryogenic processing technologies. Although the techniques are very different, the rubber materials produced are visually very similar to each other. Some differences exist in the microstructure of the rubber materials, with cryogenic processing leading to much smoother surface edges on the rubber granulate than ambient grinding. The processes and differences are outlined below.[9]

4.2 Ambient size reduction

4.2.1 Ambient size reduction is currently the most common and cost-effective method of processing used tyres in the UK. The systematic nature of the processing plants (which can progressively reduce rubber to finer and finer forms through progressive grinding techniques) allows processors to meet the demand for a particular size of tyre-derived rubber material at the most effective cost-benefit point. If a processor wishes to expand into another market (e.g. for rubber powders), the installation of an additional grinding unit may facilitate this at a relatively low cost.

4.2.2 The process (Figure 4.1) is as follows:

a. Used tyres are fed into a shredding machine that reduces the tyre size by slicing, often with fixed rather than floating knife blades. The size range of this primary shredding is in the range 50–300mm, and produces tyre cuts and shreds. At this stage, the cuts and shreds may be collected for secondary reuse.

b. Following the initial size reduction, the tyre shreds pass into a granulator, which uses a cutting and shearing action to reduce the rubber into small sizes of between 10 and 50mm. The rubber material is sifted through a mesh screen of fixed size.

c. The rubber material passes through a magnetic separation stage, where steel wire is removed. A process termed air-gravity separation (forced air or aspirator) is often employed to remove the fibre from the rubber material.

d. If finer material is required, the rubber may pass through a progressive series of granulation machines, each with fixed mesh sizes. One of the drawbacks of ambient grinding is that there is a narrow particle size distribution per grinding stage. This requires a progressive series of grinders with fixed mesh screens to produces finer and finer grades of rubber material.

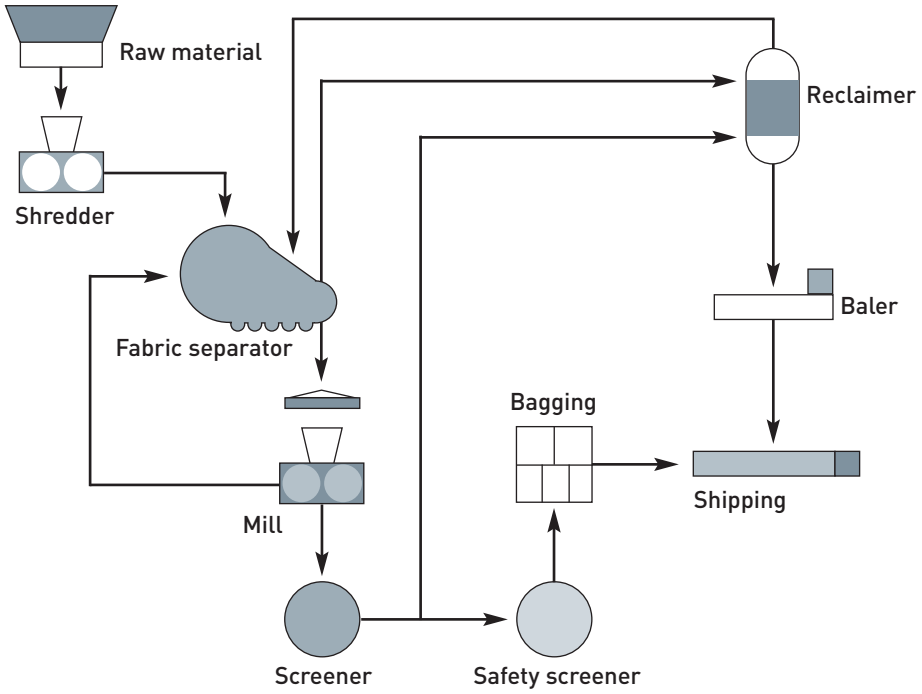
e. Rubber particles and dust are collected at each grinding stage using a suitable filtration system. This material may often be recovered and reworked back into finer material if required.

f. There may be some additional process stages, e.g. secondary collection of metallic elements via magnetic removal.

g. The very finest granulate powder may require grinding in a wet process, where the rubber is reduced in size within a liquid medium. This is termed micromilling and can produce particles of sizes down to ≤100µm. This wet process can potentially cause some leaching of organic and metal compounds from the rubber as it is ground. However, this could be beneficial for applications where the product may be used in a sensitive environment. The wet process also requires additional energy to dry the powder once it is processed to the desired size.

9 The process descriptions are based on information extracted from WRAP (2006b) and Blumenthal (2003).

Figure 4.1 Example of an ambient grinding process flow



Source: WRAP (2006b) (originally published in The Scrap Tire & Rubber Users Directory 2005).
Note: Magnets are used throughout the process.

4.2.3 The rough surface of ambiently ground rubber materials gives a large surface area. There are certain applications where this is an important attribute – notably in the construction industry and surface engineering sector where the rough surface of the rubber particles enables improved bonding with other additives and aggregates. This is especially the case in bound rubber mats, where larger rubber granules are used rather than very fine powder.

4.2.4 The maintenance costs associated with keeping the cutting equipment in a sharp condition are high and the process does have a tendency to use more power (kWh) per tonne of rubber processed than cryogenic techniques. However, the process has the undoubted advantage that it produces material with a wider range of applications.

4.3 Cryogenic size reduction

4.3.1 Cryogenic size reduction of tyre-derived rubber materials is a new technology in the UK, though it is well established in both the USA and Europe. There have been several recent announcements of private investment supporting the design and construction of a cryogenic tyre processing plant in the UK.

4.3.2 The first such plant is expected to be at Baglan, Port Talbot, in South Wales. This plant will produce high grade tyre-derived rubber materials, predominantly for use in sports surfacing applications, where the microstructure of the rubber reportedly gives advantages in dynamic stability and anti-migration properties.

4.3.3 Cryogenic size reduction of tyre-derived rubber materials differs from ambient size reduction in that it is more expensive to operate and requires a supply of cooled liquid nitrogen to maintain process efficiency.

4.3.4 The process (Figure 4.2) is as follows:

a. The first stage is preliminary shredding to reduce the tyres to smaller slices suitable for passing through the cryogenic freezing tunnel. The machinery used may be similar or identical to that for ambient shredding. The initial size reduction is variable depending on the process and the size of the final product required.

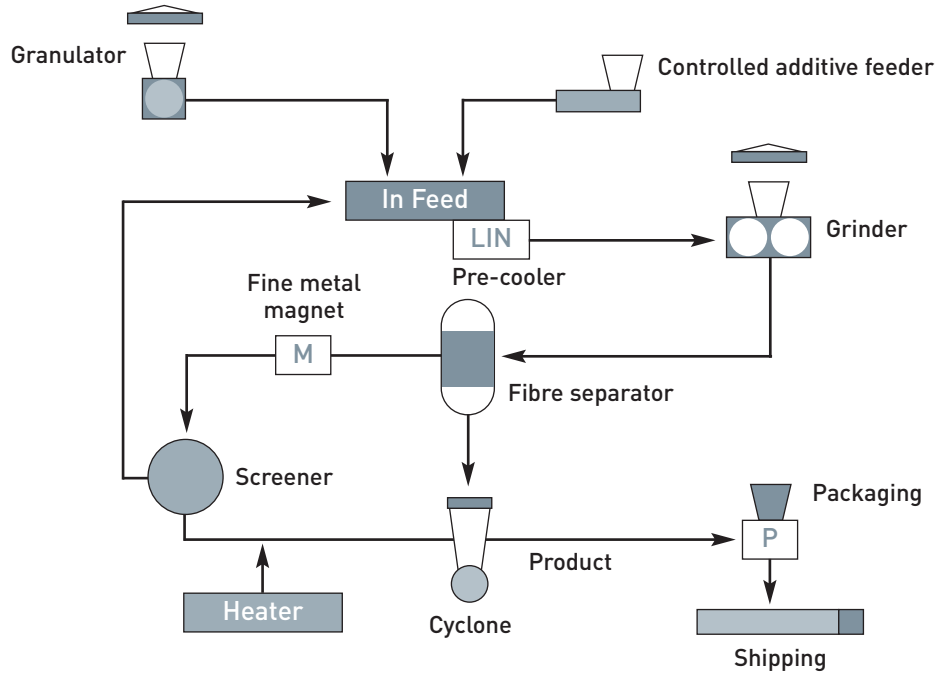
b. Depending on the process, the rubber may be pre-cooled before being passed through a tunnel of liquid nitrogen (bath or spray), which is held at a temperature of approximately 77K or –195.8°C.

c. In order to increase the efficiency of the cryogenic process and to recover the cooling energy held within the rubber material treated with liquid nitrogen, the processing often involves passing the rubber through a countercurrent heat exchanger which recovers a large proportion of the cooling energy from the tyre shreds prior to pulverisation.

d. The frozen rubber is then pulverised in a hammer mill using either swinging hammers or hydraulic presses. This process shatters the rubber into very small fragments in the size range of 600µm to 125µm, with the bulk of the rubber granules being around 200–150µm in size.

e. Mesh sieves are then used to collect the various grades of granulated rubber for packaging and transportation.

Figure 4.2 Example of a cryogenic process flow



Source: WRAP (2006b) (originally published in The Scrap Tire & Rubber Users Directory 2005).

4.3.5 The rubber materials produced from cryogenic processing plants can be used in a limited number of market applications. The cost of the processing and the crystalline smooth structure of the rubber particles mean that rubber produced by this method is better suited to some higher value applications such as sports surfacing.

4.3.6 The wider particle size distribution of cryogenically produced tyre-derived rubber materials also means that it is far better suited to producing finer granulates and powders than producing fine powder via ambient means (this would incur very high processing costs with multiple grinding sequences). This suggests that the current UK market for tyre-derived rubber materials could support both cryogenically and ambiently produced materials for differing applications.

4.3.7 Another potential feature of the cryogenic process is that the steel recovered from the process is in a near perfect condition, maximising its value on the materials recovery/recycling market.

5. Material composition

5.1 Chemical composition

5.1.1 Tyres are manufactured using a range of compounds to produce a polymer suitable for a very large range of applications from high performance sports and racing cars through to large earth-moving machinery. The exact composition of tyres is very dependent on the actual application, giving too many variations in specification to list in this report. Instead attention is paid to the compounds that are most widely used in tyre rubber formulation.

5.1.2 A scoping review published by the Environment Agency's Chemicals Assessment Unit (CAU) sought to characterise the environmental risks from chemicals used in the rubber industry (Environment Agency 2005). This document contains useful data on the typical chemical composition of rubber car tyres and gives examples of the key compounds (Table 5.1).

Table 5.1 Chemical composition of car tyres

Component	Percentage	Examples
Rubber	40–60	Natural rubber Isoprene rubber Styrene–butadiene rubber Butadiene rubber Chlorobutyl rubber
Reinforcement aids	25–35	Carbon black Silica Novolac resins
Softeners	15–20	Highly aromatic oils or replacements
Vulcanisation agents	1–2	Sulphur
Accelerators	0.5–2	Thioureas Sulphenamides
Activators	2–5	Zinc oxide + fatty acid Zinc stearate
Anti-degradants	1–2	p-phenylenediamines Dihydroquinoline derivative Nonylphenols

Source: Environment Agency (2005)

5.1.3 The processing of used tyres – either ambiently or cryogenically (see Section 4) – does not in any way alter the composition of the rubber. Metal and fibre is removed (in varying quantities) during processing but, essentially, the process changes the physical characteristics while maintaining the chemical composition.

5.1.4 Research suggests that a car tyre will shed approximately one kilogram of its rubber onto the road during its useful lifespan (Environment Agency 2005). However, it will also 'pick up' (chemically integrate) certain chemical compounds from the road surfaces – notably organic chemicals such as combustion by-products and aromatics such as benzene derivatives.

5.1.5 There have been no studies on the level of organic chemical contaminants a tyre is likely to pick up during its service life. Investigations based on the typical composition of tyre rubber indicate that the compounds a tyre might pick up are likely to have already been used in the initial manufacture of the tyre – either as a raw material used for a specific property or as a contaminant in one of the ingredients (RMA 1993).

5.1.6 The human health and environmental risks associated with the chemicals typically found in used car tyres (and hence tyre-derived rubber materials) are discussed in Section 8 of this report.

5.2 Physical characteristics

5.2.1 The physical characteristics of the rubber are determined, to a large extent, by which processing method is used. Ambient grinding leaves the surfaces of the rubber particles with a rough, jagged texture and a very large surface area relative to that of the original tyres. Cryogenic processing produces a very smooth and more rounded rubber particle with less surface area than ambiently ground rubber.

5.2.2 The physical characteristics of the tyre-derived rubber materials are the most significant feature associated with end use – the primary parameter being the size of the rubber shred, chip or particle. It is generally accepted that the smaller the rubber particles, the higher the cost of processing and therefore the higher the cost to the end user.

5.2.3 The larger sizes of tyre-derived rubber materials are likely to contain higher levels of both metal and fibre that may limit their potential application.

6. Material specification and quality standards

6.1. Specifications for tyre-derived rubber materials

6.1.1 Market end uses dictate the specifications and quality standards that would be required. Two such product applications are described below.

- In a less complex application such as the use of rough rubber cuts in a drainage layer, the rough nature and irregular sizing of the tyre-derived rubber materials are essential for the correct functioning of the drainage layer. Such characteristics create air pockets and voids that facilitate the drainage of liquid from above.
- In a more complex application such as the use of fine rubber powders as an additive in mastic and high-performance sealant products, the specification of the tyre-derived rubber materials is set by the end user and is generally far more prescriptive. Such applications require the processor (often by way of a supply contract) to ensure the specification of such materials is within a prescribed series of parameters which may include surface texture, size, density, contamination levels, etc.

6.1.2 It is clear from these two examples that a single unified specification for tyre-derived rubber materials would not be suitable or applicable to existing or potential future end uses.

6.1.3 It is also clear that the market end use predominantly defines the specifications that the material will be required to be processed to. For example in sports surfacing applications, rubber particles are generally specified to be supplied in the smaller size range 1–4mm, although certain sports surfacing applications may require larger or smaller sizes.

6.1.4 Thus defining a standard may not be practical nor provide sufficient flexibility.

6.2 Standards for ambiently ground tyre-derived rubber materials

6.2.1 At present, there are no agreed and certified standards for processing of used tyres into tyre-derived rubber materials although a number of standards do exist for the testing of material quality.[10]

6.2.2 BS PAS 107 contains a series of quality standards and material specifications.[11] Because PAS 107 has been developed in consultation with industry, it should form the primary reference document for manufacturers and users of tyre-derived rubber materials. At present, the requirement to process used tyres according to the specification in PAS 107 is voluntary although, in order to produce a tyre-derived rubber material that has certainty of use, the specifications contained within PAS 107 should be followed.

6.2.3 It is recommended that PAS 107 should remain as a 'live' document, being updated to reflect market changes and technologies as appropriate.

6.2.4 Certain voluntary specification sheets have been developed regarding the sizes of tyre-derived rubber materials, notably by Charles Lawrence International Ltd, which supplies various grades of material each with its own material safety datasheet, an example of which is provided as Appendix E.[12]

6.2.5 Certain German DIN (Deutsches Institut für Normung e. V.) standards are available against which tyre-derived rubber materials can be tested. However, test results against these standards had not been received by industry at the time of writing this report. It is recommended that the test results are reviewed, when available, with a view to assessing their potential use as an addition or alternative to PAS 107. The DIN standard would offer the only available externally accredited standard for rubber materials derived from waste tyres.

10 See Tables 8, 9 and 10 of WRAP (2006c).
11 Available from http://www.wrap.org.uk/construction/tyres/tyres.html
12 http://www.clgplc.co.uk/index.php?option=content&task=view&id=10&Itemid=33&parent=28&group=clicontent

6.3 Standards for cryogenically produced tyre-derived rubber materials

6.3.1 PAS 107 is only applicable to ambiently ground tyre-derived rubber materials and therefore does not cover materials produced using cryogenic technology.

6.3.2 The TAG proposed that PAS 107 could also apply to manufacturers of cryogenically produced tyre-derived rubber material. The production process is the only section of PAS 107 that may vary, but the TAG suggested that the principles of this section (7.3) should be applied by cryogenic processors (i.e. the record-keeping requirements).

6.4 Independent certification and material verification

6.4.1 The TAG discussed at some length the issues relating to independent testing, certification and verification of tyre-derived rubber materials. At present, no specific regime regarding the certification of material quality has been established at an industry-wide level, although some larger manufacturers do test and publish specification sheets confirming the quality of their materials.

6.4.2 Those tests that are conducted are typically made against a number of specifications (required by the consumer as important characteristics of the rubber materials). Although these specifications are detailed in PAS 107, they are illustrative and, as it is a voluntary specification, there is no requirement at present for common independent certification of tyre-derived rubber materials.

6.4.3 The TAG also discussed issues surrounding the appointment of an independent, certified body to perform material verification and to certify it had been produced to a standard. TAG members felt that, while there were auditing bodies in the UK that could perform such a task (e.g. BSI), there was no single trade organisation that could perform the role of administering such a system on behalf of all manufacturers.

6.4.4 The primary reason given for this view was that a trade organisation's role is to serve its members and those who are not members would not be captured unless they signed up to join. Many manufacturers may not wish to sign up to one particular trade body and the act of using a single body as an administrator of a certification scheme could be interpreted as a restriction of free choice and potentially non-competitive.

6.4.5 The TAG proposed that there should be a mechanism for independent accreditation and certification of manufacturers of tyre-derived rubber materials to Quality Protocol standard. However, the TAG concluded that there was not a clear direction or way forward at the present time and that this issue should be raised as a consultation question. Presenting the issue as a consultation question will allow comment from a wider group of stakeholders and may ultimately provide a suitable way forward.

7. Environmental impacts and assessment

7.1 A number of studies published since the mid-1970s in the UK, USA and Europe have sought to quantify the environmental impacts of using recycled or recovered tyres for a wide range of secondary purposes. The available literature was subjected to an extensive review before compiling this environmental impact and assessment section. Table 7.1 presents a summary of the most significant findings and information drawn from these sources.

Table 7.1 Summary findings and outcomes from selected research articles as part of the literature review

Study title	JL Testing Co. Inc., 1989 *Tire chip evaluation – permeability and leachability assessments*. Report 89R414-01. Summary report for Waste Management of North America Inc.
Key summary	Report assessed the feasibility of using tyre chips as a suitable medium for landfill drainage applications. The leachate was assessed using leachate column testing for duration of 114 days.
Conclusions	Permeability of the tyre chips increases by two orders of magnitude with rising loads from 4,000 pounds per square foot (psf) to 20,000 psf. Temperature had little to no effect on permeability.
Interpretation	When used in load-bearing application such as drainage layers, tyre chips increase the permeability (and hence their ability to leach chemicals) with increasing loads.
Study title	Biever R C, 1995 *A comparative study of the toxicity of chipped tires and wood chips leachate*. Report SLI#95-10-6161 by Springfield Laboratories Inc. for the Minnesota Department of Transportation.
Key summary	Laboratory-scale testing involved using leachate from chipped tyres that had been soaked in water for varying amounts of time. Leachate was analysed for base/neutral extractables (using EPA Method 625) and for metals. The octanol–water partition coefficients (log_{Pow}) were estimated from a resolved peak using high-performance liquid chromatography (HPLC). The study examined toxicity to three aquatic indicator species, water flea (*Ceriodaphnia dubia*), fathead minnow (*Pimephales promelas*) and green algae (*Selenastrum capricornutum*) and two terrestrial species, earthworms and lettuce. ■ Daphnid 48 hr-LC_{50} was a leachate concentration of 6.3 per cent; NOEC* was 3.1 for survival. ■ Fish 48 hr-LC_{50} was a leachate concentration of 8.9 per cent; NOEC was 6.3 per cent for survival. ■ Algae growth was inhibited at all concentrations with no growth at greater than 50 per cent concentration. ■ Lettuce growth was stimulated by 13–25 per cent. ■ No observed effect in earthworms up to theoretical values of 1.1mg/kg. Analysis of the leachate showed metal concentrations at the following levels: ■ mercury (0.4µg/l); ■ lead (3.1µg/l); ■ barium (36.7µg/l); ■ zinc (2,950µg/l). * NOEC is 'no observed effect concentration' i.e. the concentration at which no effects are observed (detrimental or otherwise) on test subjects.
Conclusions	The toxicity of leachate to aquatic organisms correlated strongly with the concentrations of zinc within the leachate. Both wood and chipped tyre leachate reduced dissolved oxygen levels in the water.
Interpretation	Leachate from the use of chipped or granulated rubber tyres may pose a potential risk to aquatic organisms at concentrations above 3.1 per cent. Therefore, the most sensitive habitats would be still water bodies where reduced levels of dilution over time may lead to the build-up of potentially harmful concentrations of tyre leachate. There would appear from this research to be negligible risk to terrestrial species from the use of tyre chips or any leachate produced.

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Table 7.1 Summary findings and outcomes from selected research articles... cont.	
Study title	Rubber Manufacturers Association, 1993 *Study of waste tire leachability in potential disposal and usage environments*.
Key summary	This study examined the effect on the aqueous environment of leachate associated with the use of tyre chips. The study utilised both laboratory controlled tests and a field study using material as part of a drainage trench for sewage from residential housing.
Conclusions	In a series of 10 controlled laboratory tests, organic and metal compounds were leached from the tyre chips in all cases. The field study showed a lower level of leaching than laboratory experiments. Tyre shreds were found to have the potential to absorb Pb (II) and Cd(II) from the surrounding environment. Organic compounds leached included benzene and 1,2,3 trimethylbenzene. It was found that levels of leaching reduced greatly after the first 30 days. Concentrations of benzene in leachate were greatest in the smaller tyre chips (0.5 × 0.5 inches), although the concentrations fell rapidly to levels lower than other larger size chips/shreds within 30 days. Concentrations of zinc were also found to be significantly lower after 30 days.
Interpretation	Tyre chips placed in contact with water have the potential to leach out metallic and organic compounds including benzene and zinc. Concentrations would appear to drop after a relatively short environmental exposure period of 30 days, supporting other research that states the primary impact is during initial rapid degradation of the top layer of the rubber.
Study title	Rubber Manufacturers Association, 2001 *Five-year study of the water quality effects of tire shreds placed above the water table*.
Key summary	Two field trials used tyre shreds of sizes <50mm, with exposed wire remaining in the rubber. The Richmond field trials found low levels of metals leached, notably zinc with a slightly elevated level of manganese. The North Yarmouth field trials showed similar results with concentrations of all apart from manganese below US drinking water standards.
Conclusions	Most of the organic substances that can be leached from tyre shreds are naturally present in the ground/groundwater. No evidence was found of elevated zinc levels.
Interpretation	This research contradicts previous study findings that zinc concentrations were elevated, although the field test conducted in 1993 (see above) did show reduced levels of metals in leachate when tested in-situ. The tests conducted in this study were on relatively large shreds of tyre and may not therefore be representative of the smaller loose granular sizes <10mm.
Study title	Environment Agency, 2004 *Lifecycle assessment of the management options for waste tyres*. R&D Technical Report P1-437/TR.
Key summary	This study looked at wide-ranging impacts from the reuse of used tyres in a number of applications. The study also sought to quantify the human toxicity and aquatic, terrestrial and marine ecotoxicity of the various management options. However due to extreme uncertainties in the methodologies, the results cannot be interpreted as being wholly representative of actual impacts.
Conclusions	Rubber crumb for flooring surfaces was estimated to generate the most significant impact in terms of aquatic freshwater toxicity effects, with the use of rubber shred as a drainage filler having the most significant photochemical and abiotic degradation effect.
Interpretation	No clear interpretation can be made based on these figures.

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Table 7.1 Summary findings and outcomes from selected research articles... cont.

Study title	Environment Agency, 2005 *Characterising environmental risks from the rubber industry – a scoping review* [draft].
Key summary	This research focused primarily on the risks from the chemicals and compounds used during rubber manufacture and manufacture/use of the rubber articles during their service life. Some discussion is made on pages 26-27 regarding the ecotoxicity of tyre leachate and a summary of a narrow literature review is made. The report indicated that certain substances that are used in the manufacture of rubber products (including tyres) are listed as substances of concern (due to potential for persistence/bioaccumulation/toxicity). From the literature review, three studies (Collins *et al*. 1995, Vashith *et al*. 1998 and O'Shaughnessy and Garga 2000) all showed that zinc leached out at a higher rate than other metals, although there was an early peak of concentration and leaching only occurred on the outer 2mm of rubber.
Conclusions	Used tyres are likely to contain substances of high concern that are subject to ongoing (or completed) European Chemical Risk Assessments under the Existing Substances Regulation No. 793/93/EC.
Interpretation	Tyres do contain at least three chemicals (potentially more in some formulations) that are on the Priority Substances List under Council Regulation No. 793/93/EC (Existing Substances Regulations). There also exists the potential for zinc and other metallic compounds to leach from tyre-derived rubber materials, particularly in the finer grade of material. Certain indications point to ultraviolet (UV) degradation of the upper layer enhancing the leaching effect by degrading the outer surface of the rubber. It is also made clear by research summarised in this report that leachate from tyre chips was not considered to be a significant source of environmental pollution compared with the rubber dust that is washed into the environment from the sides of roads and motorways in the UK.
Study title	National Institute for Public Health and Environment (RIVM), 2006 *Risk reduction strategy and analysis of advantages and drawbacks for zinc metal and five zinc compounds. Final report*.
Key summary	Zinc metal and its compounds required a risk assessment under the Existing Substances Regulation (793/93/EC). This risk assessment included zinc oxide (ZnO), which is used in significant quantities by European tyre manufacturers (26 per cent of the total production). Each tyre can contain 1–1.5 per cent zinc oxide by weight. The report did not make conclusions or propose a need for risk reduction measures to be implemented in order to reduce or control the environmental risk from emissions of zinc oxide associated with the use of tyre-derived rubber materials. However, the report did reach conclusions on regional risks for all zinc compounds. These can be summarised as:

Type of ecosystem	Conclusion reached	
Surface waters	run-off from motorways	1
	regional surface waters	3
Sediments	regional waters	3
Terrestrial environments	agricultural soil	2
	road borders	1

Key **1** Requirement for more testing; **2** No requirement for further testing and/or risk reduction measures beyond those currently in place; **3** Need for limiting the risks, reduction measures already in place will be taken into account.

Conclusions	There is a need to limit the risks to the aquatic environment (regional surface waters and sediments) from the effect of zinc and its compounds. Existing measures should be taken into account.
Interpretation	The conclusions of this report point to the fact that there may be clear evidence (or based on limited scientific understanding – precautionary principle) that zinc has the potential to impact on regional aquatic ecosystems. It would therefore seem appropriate that certain applications for tyre-derived rubber materials require risk reduction measures to reduce the potential for environmental impact where such a potential may exist. These measures are considered in Section 8 of this report.

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Table 7.1 Summary findings and outcomes from selected research articles... cont.	
Study title	Remade Scotland, 2006a *The impact on the environment and human health of waste tyre reuse in engineering applications*.
Key summary	This report included a significant literature review of existing research on the impact of tyres and associated leachate products when used in the environment for secondary purposes. The report looked not only at the use and type of rubber used but also at the environmental conditions that would approximate to certain indicative uses (i.e. acidic environments).
Conclusions	It was concluded that, based on research reviewed in producing this report, the use of tyre-derived rubber materials should be restricted in a number of environments, as presented below. ***Environments with exposure to UV light*** Rubber degrades and loses its structural integrity if exposed to UV light .This significantly reduces the design life of any structure comprising of tyres or tyre-derived materials. In addition, the majority of toxin release from tyres is from those parts degraded by exposure to UV light. ***Environments with a high tyre surface area to mass ratio*** The availability of oxygen has been established as the limiting factor in the ignition and persistence of tyre fires. Voids should be minimised by compressing tyres into bales, or reducing air void volumes by infilling with inert material or submersion in water. ***Freshwater environments where water circulation is low*** It is possible that small freshwater pools of standing water exposed to run-off from tyres or containing submerged tyres could be at risk of negative environmental effects if this initial leachate can not disperse. Various studies have shown that the toxic effect of leachate from tyres is greater in freshwater environments than in marine environments. A number of further studies have shown that unrinsed tyres used in environments with a tyre-to-water ratio greater than 2kg per 100 litres are 100 per cent lethal to rainbow trout hatchlings. This effect is commonly attributed to the presence of zinc in the leachate. However, a number of papers note that this leachate contains numerous unidentified organic compounds and that the leachate is still 100 per cent lethal when the zinc is removed. This effect was no longer evident after an initial immersion period of 60–90 days. ***Freshwater environments with uncommonly low or high pH values*** Although it is known that an acidic environment will promote the release of metals and an alkaline environment will promote the release of organic materials, no case studies could be found that with environments of unusual pH. It would be prudent to restrict the use of tyres in such environments until further study is carried out to confirm this.
Interpretation	Certain substances may leach out of tyres (particularly smaller granular rubbers) when used in certain environments, notably in unbound applications. It has been shown through various research studies that leachate from shredded or crumbed used tyres can have a potentially toxic effect on aquatic ecosystems. There is a substantive amount of research that would support this case, though a definitive chemical or compound has not been linked directly with the toxic effect. In areas where run-off (or particulates) from tyre-derived rubber materials could enter surface waters exists, it would be prudent to implement suitable mitigation and/or containment measures.

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Table 7.1 Summary findings and outcomes from selected research articles... cont.

Study title	Remade Scotland, 2006b *Risk assessment of the impact on the environment and human health of waste tyre reuse in engineering applications*.
Key summary	A review of case studies regarding the effects of waste tyre reuse in engineering applications was carried out to establish the identified risks to human health and the environment. The following hazards appropriate to the uses of tyre-derived rubber materials noted in this report were identified: 1. leaching of metals; 2. leaching of organic compounds; 3. fire; and 4. occupational health risks of waste tyre processing. The following consequences were identified: ■ reduction in diversity and the number and health of species in the surrounding environment due to the leaching of metals; ■ pollution by metals of waters used for the abstraction of drinking water; ■ reduction in diversity and the number and health of species in the surrounding environment due to the leaching of organic compounds; ■ pollution by organic compounds of waters used for the abstraction of drinking water; ■ loss of habitat for flora and fauna affected by fire; ■ injury or death by fire to local population; ■ air pollution from smoke from tyre fires; ■ soil pollution from ash from tyre fires; ■ high noise levels associated with the processing of tyres into shred/crumb; and ■ respiratory disease associated with dust generated from the production of tyre scraps and tyre crumb.
Conclusions	For the main identified environmental hazards (hazards 1-3 above), the magnitude of the consequences of these hazards occurring was assessed by a team including environmental engineers and scientists. They concluded that each of these hazards would rate as the most significant category i.e. SEVERE. The probability of the hazard occurring was also assessed. For the purposes of this technical report, the only use scenario applicable was the probability of hazard occurring from the use of crumb and shred tyres in a land environment. The outcome of the assessment was that there was generally a HIGH probability for leaching of metals and organics, and a NEGLIGIBLE–LOW probability of fire and dispersal. The product of these parameters is a risk factor, which was also assessed as part of the study. For the use of shredded/crumbed tyres in a land environment, the risk was assessed as being MEDIUM–HIGH, with more scenarios resulting in a HIGH risk than a MEDIUM. The most significant influencing factors were lack of dilution in the receiving environment and an environment with extreme ranges of pH. This would appear to support the findings of previous research.
Interpretation	The use of tyre crumb and shred has a high potential of occurrence, severe consequences and a high level of associated risk in aquatic environments where there is low dilution potential and in areas where pH are extreme. It is recommended that mitigation and risk reduction/control measures should be implemented when crumb and shred are used in applications where either the material or the leachate/run-off could enter surface waters (directly or through groundwater). It is considered prudent not to use tyre crumb and shred in areas where pH is extreme.

7.2 The potential impact of the use of tyre-derived rubber materials on human health and the environment in the most common market applications can be summarised as follows:

- In general, the use of tyre-derived rubber materials is not likely to cause a detrimental impact on human health or give rise to significant environmental impacts.
- Scientific research indicates that there is limited risk of an impact on the environment from the use of tyre-derived rubber materials in land applications (where leachate and/or surface water run-off does not drain into a surface water body such as a river, pond or stream).
- The most significant environmental impacts are likely to be from the leaching of organic and metallic compounds from the surface of the rubber. The primary contaminants are expected to be zinc, PAHs and benzothiozoles. Secondary contaminants include cadmium, iron, manganese and other organic compounds. The impact of these is restricted to surface waters.
- Leachate containing organic and metallic compounds is likely to be more of an issue from finer grades of tyre-derived rubber materials as these have a greater surface area to mass ratio.
- The toxicity of leachate from tyre-derived rubber materials is most notable in aquatic environments and is influenced by the degree of dilution prior to, and upon entry to, the water body. Faster flowing rivers and streams are not likely to suffer significant environmental impact. Slow flowing streams, ponds and pools are more likely to be affected.
- There has not been scientific agreement on exactly which compounds contained within tyres may prove toxic to freshwater organisms and aquatic species. Further research is necessary to ascertain this.
- The toxic effect of leachate from tyre-derived materials reduces rapidly with time and it is likely that washing of tyre-derived rubber materials prior to land application would reduce the potential leaching of contaminants to levels that would have a very limited or negligible environmental impact.
- Certain compounds contained within used tyres (including zinc, PAHs and nonylphenols) are listed as substances under the Existing Substances Regulation No. 793/93/EC for which a risk assessment and, if necessary, a risk reduction strategy must be developed by Member States. As tyre-derived rubber materials contain such substances that may be released into the environment, the findings of such reports (in particular the risk reduction measures) should be taken into account when assessing the use of such materials in certain unbound applications.

8. Risk assessment

8.1 Table 8.1 presents the results of a detailed risk assessment undertaken by the TAG of the production and use of tyre-derived rubber materials produced from used tyres.

8.2 Based on this risk assessment, the TAG considers the risks of the identified hazards to be low provided appropriate mitigation measures are adopted. Proposed measures are shown in the shaded column of Table 8.1.

Table 8.1 Results of risk assessment undertaken by the TAG

Application/use	Hazardous event and potential pathway	Receptor(s)	Risk before mitigation			Mitigation measures required*	Risk after mitigation		
			H	M	L		H	M	L
Civil engineering (non-road): construction aggregates drainage fillers block applications landfill stabilisation landfill drainage layers railway crossing matting	Leaching of contaminants into terrestrial environment via surface run-off or groundwater transportation	Terrestrial habitats Groundwater Flora & fauna Humans			✓	Research has shown a low probability of environmental effects in the terrestrial environment – no mitigation proposed.			✓
	Leaching of the contaminants into the aquatic environment via surface run-off or groundwater transportation	Aquatic habitats Flora & fauna Humans		✓		Research suggests that leachate from tyre-derived rubber materials in loose applications may be toxic in aquatic environments. Where a potential pathway direct to surface waters exists (e.g. fillers in open surface drainage channels): ■ develop suitable containment mechanisms and/or leachate collection systems; ■ ensure adequate dilution at the receptor (fast-flowing river/stream) if an open pathway is unavoidable.			✓
	Fire risk during interim storage of materials on-site prior to use	Air Terrestrial habitats Flora & fauna Humans		✓		Certain conditions can be created during storage of rubber crumb and shred that can lead to oxidation and exothermic reaction causing fire risks. In all cases, the risks should be minimised by: ■ covering the rubber material and increasing the mass to surface area ratio to limit air pockets; ■ keeping well away from sources of heat and ignition (including heaters); ■ limiting the size of the stock piles to <3m in height and separating storage cells with fire-resistant dividing panels; ■ reducing the explosive atmosphere risk by managing dust generation when using rubber granulate (powders).			✓

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Table 8.1 Results of risk assessment undertaken by the TAG cont.

Application/use	Hazardous event and potential pathway	Receptor(s)	Risk before mitigation			Mitigation measures required*	Risk after mitigation		
			H	M	L		H	M	L
Civil engineering (road): rubberised asphalt highway drainage layer roadway base	Leaching of contaminants into terrestrial environment via surface run-off or groundwater transportation	Terrestrial habitats Groundwater Flora & fauna Humans			✓	Research has shown a low probability of environmental effects in the terrestrial environment – no mitigation proposed.			✓
	Leaching of the contaminants into the aquatic environment via surface run-off or groundwater transportation	Aquatic habitats Flora & fauna Humans		✓		Research suggests that leachate from tyre-derived rubber materials in loose applications may be toxic in aquatic environments. The pathway from rubberised asphalt is not available but, in loose fill drainage or aggregate applications below the water table, leachate may be generated. Ensure that surface pathways do not exist to sensitive surface waters within 50m of the site.			✓
	Fire risk during interim storage of materials on-site prior to use	Air Terrestrial habitats Flora & fauna Humans		✓		Certain conditions can be created during storage of rubber crumb and shred that can lead to oxidation and exothermic reaction causing fire risks. In all cases, the risks should be minimised by: ■ covering the rubber material and increasing the mass to surface area ratio to limit air pockets; ■ keeping well away from sources of heat and ignition (including heaters); ■ limiting the size of the stock piles to <3m in height and separating storage cells with fire-resistant dividing panels; ■ reducing the explosive atmosphere risk by managing dust generation when using rubber granulate (powders).			✓

continues overleaf

Table 8.1 Results of risk assessment undertaken by the TAG cont.

Application/use	Hazardous event and potential pathway	Receptor(s)	Risk before mitigation			Mitigation measures required*	Risk after mitigation		
			H	M	L		H	M	L
Sports, leisure, safety surfacing and recreational activities	Leaching of contaminants into terrestrial environment via surface run-off or groundwater transportation	Terrestrial habitats Groundwater Flora & fauna Humans			✓	Research has shown a low probability of environmental effects in the terrestrial environment – no mitigation proposed.			✓
Bound applications: Safety surfacing Playground matting	***Bound applications ONLY*** Leaching of the contaminants into the aquatic environment via surface run-off or groundwater transportation	Aquatic habitats Flora & fauna Humans		✓		Research has shown a low probability of environmental effects in the terrestrial environment – no mitigation proposed.			✓
Unbound applications: Artificial turf/ Sports surfaces Ménage areas Raceways and tracks Trails and paths Park play areas	***Unbound applications ONLY*** Leaching of the contaminants into the aquatic environment via surface run-off or groundwater transportation	Aquatic habitats Flora & fauna Humans			✓	Research suggests that in loose applications, where a large surface area of tyre-derived rubber materials is present, there exists the potential for significant localised environmental effects in aquatic environments, notably from the toxicity of leachate contaminated with organic and metallic compounds. When using tyre-derived rubber materials in loose applications, the following measures should be applied: ■ ensure no pathway exists for surface water run-off directly to surface waters (ponds/streams). If this is not possible and a potential pathway is found to exist: ■ ensure adequate dilution at the receptor (fast-flowing river/stream); ■ contain any potential leachate and treat as per normal sewage water; ■ contain the tyre-derived rubber particles using barrier methods to prevent free release into the environment.			✓

continues overleaf

Table 8.1 Results of risk assessment undertaken by the TAG cont.

Application/use	Hazardous event and potential pathway	Receptor(s)	Risk before mitigation			Mitigation measures required*	Risk after mitigation		
			H	M	L		H	M	L
Sports, leisure, safety surfacing and recreational activities cont.	Fire risk during interim storage of materials on-site prior to use	Air Terrestrial habitats Flora & fauna Humans		✓		Certain conditions can be created during storage of rubber crumb and shred that can lead to oxidation and exothermic reaction causing fire risks. In all cases, the risks should be minimised by: ■ covering the rubber material and increasing the mass to surface area ratio to limit air pockets; ■ keeping well away from sources of heat and ignition (including heaters); ■ limiting the size of the stock piles to <3m in height and separating storage cells with fire-resistant dividing panels; ■ reducing the explosive atmosphere risk by managing dust generation when using rubber granulate (powders).			✓
Industrial applications ***Bound applications:*** Carpet underlay Sealant and mastics Roofing tiles Sound-proof matting Moulded rubber products	Leaching of contaminants into terrestrial environment via surface run-off or groundwater transportation	Terrestrial habitats Groundwater Flora & fauna Humans			✓	Research has shown a low probability of environmental effects in the terrestrial environment – no mitigation proposed.			✓
	Leaching of the contaminants into the aquatic environment via surface run-off or groundwater transportation	Aquatic habitats Flora & fauna Humans			✓	Given the nature of the industrial products, the potential for leachate generation is minimal and no further mitigation measures are proposed.			✓
	Fire risk during interim storage of materials on-site prior to use	Air Terrestrial habitats Flora & fauna Humans			✓	Given the bound nature of the industrial products, the potential of fire is minimal (a minimum temperature of 350°C must be maintained to ignite and sustain a fire on such bound rubber materials). Store bound rubber products away from sources of ignition or incandescent materials and protect stores from vandalism that may lead to introduction of such a source of ignition. No further mitigation measures are proposed.			✓

8.3 Discussion on risks

8.3.1 A number of research studies give conflicting evidence on the potentially harmful environmental effects from the use of tyre-derived rubber materials.

8.3.2 Evidence suggests that:

- there is a potential for rubber material once chipped or shredded to have an outer layer of contamination that may run-off once in contact with water; and
- UV radiation (primarily from sunlight) can degrade the top surface of tyre-derived rubber, potentially releasing chemical compounds (from the top 2mm of rubber) which may be transported into the environment by rainwater or surface run-off.

8.3.3 Potential harmful effects have been suggested to occur when leachate is produced when tyre-derived rubber materials are placed in contact with water (either rainwater or groundwater). These effects are generally understood to be limited to the ecosystems of sensitive aquatic environments such as ponds, streams and small rivers where dilution is low and the toxic effects of the leachate are therefore more pronounced.

8.3.4 The risk assessment suggests that the primary risk to the environment is likely to come from the use of loose tyre-derived rubber materials where the potential exists for surface water run-off or leachate from these materials to enter a surface water environment.

8.3.5 As far as research indicates, both the potential for leachate from initial surface area exposure and UV degradation occur in the first 15 days of exposure and then decline to a point where there is no significant leachate. Enquiries revealed that no incidents have been reported to the Environment Agency regarding pollution arising from the use of tyre-derived rubber materials.

8.3.6 But to be precautionary, it is necessary to look at the potential for harm to the environment to occur in each unbound application (see below).

8.3.7 **Civil Engineering (non-road and road)**

The TAG felt that the risk of leachate in unbound engineering applications is only of medium significance and low likelihood. This is mainly because the primary use is in landfill engineering where any leachate will be captured by the containment system. Otherwise, loose rubber fill is not widely used in the UK. Applications other then landfill

- as drainage fill, which tends to be underground and therefore will have no exposure to UV radiation; and
- as loose fill (e.g. as bridge abutments) where both the rubber material and any leachate will be fully contained and protected from UV degradation. The ingress of water is also highly unlikely.

8.3.8 **Sports, leisure, safety surfacing and recreational activities**

The TAG felt that the risk of leachate in sports, leisure, safety surfacing and recreational unbound applications is only of medium significance and low likelihood. This is mainly due to:

- the materials being applied in a thin layer;
- most applications tend to be contained (e.g. football pitches) or have barriers (e.g. path edges); and
- the potential for leachate from UV exposure is minute after 30 days exposure.

8.3.9 **Industrial applications**

In light of research related to effects of UV degradation of rubbers, the TAG requested further information on the potential risk of this where there is a pathway to surface waters – notably in rubberised roofing tiles. Information provided by industry[13] suggests that:

- the level of carbon black in bonded roofing tiles is sufficient to resist long-term degradation; and
- the tiles produced using compounds of tyre-derived rubber materials would carry a 30-year guarantee against defects.

13 E-mail communication from WRAP regarding the potential degradation effects of UV exposure on bonded polymer roof tiles.

Based on the independent testing of such materials, the TAG concluded that UV degradation is unlikely to be an issue for such materials, therefore, the risk to the environment can be considered to be low.

8.3.10 In summary, the TAG concluded in its discussions that:

- in all applications, there is no risk to human health or terrestrial environments;
- in bound applications, there is no risk to aquatic environments; and
- in unbound applications, even though general application practice suggests that there is a low likelihood of leaching from unbound tyre-derived materials, the TAG suggested that to ensure adequate precaution in the use of tyre-derived rubber materials in these loose applications in close proximity to aquatic receptors, the following good practice should be adhered to:
  - do not apply in a way that may potentially cause environmental pollution (e.g. do not spread directly next to watercourses);
  - where practical, contain all loose tyre-derived materials by appropriate barrier methods (e.g. lining, kerbing);
  - maintain records that detail:
    - quantities and batch supplied and/or used;
    - application rates of tyre-derived rubber materials;
    - location of sites where tyre-derived materials have been loosely spread; and
    - date of spreading; and
  - do not use crumb and shred in areas with very high or low pH as there is greater potential for metal/organic mobilisation. This could be stipulated on the supply documentation. This advice is given in the absence of other information.

8.4 Storage of tyre-derived materials

8.4.1 The TAG discussed the interim storage of processed tyre-derived rubber materials at a site other than the manufacturing facility (or other licensed waste storage facility). It concluded that the following issues were of sufficient importance that a Quality Protocol should address them.

- The interim storage of tyre-derived rubber materials at a site other than that at which they were manufactured could, in some cases, prove critical to the winning of a supply contract and to the logistics of being able to deliver large quantities of material to the site of final end use (the customer's premises).
- Not having such a provision as part of a Quality Protocol could present a risk that manufacturers may have to cease processing of certain tyres due to limits on on-site storage capacity. This may have an impact on established collection contracts and result in an increase in the number of fly-tipping incidents involving used tyres.

8.4.2 The TAG acknowledged that there are risks associated with the storage of the tyre-derived material both on-site and at an interim location.

8.4.3 Essentially, the risks associated with interim storage sites include:

- material being abandoned, stockpiled or left for excessive periods; and
- being stored inappropriately potentially leading to environmental pollution incidents and fires.

8.4.4 The TAG agreed that these risks could be associated with a variety of other products. It was suggested that, if good practice guidance for storage were applied in the same way as with any other product, any risk would be sufficiently mitigated.

8.4.5 The TAG concluded that the information contained within Annex B of PAS 107 is suitable good practice to limit the risks to the environment. Therefore, it should be referenced in a Quality Protocol.

8.4.6 Additional good practice for interim storage was discussed and it was suggested that an operator should also:

- provide (upon request) supply documentation as evidence of 'certainty of use' prior to any interim storage of tyre-derived rubber materials;
- maintain ownership of all tyre-derived rubber materials stored at any location other than the site of manufacture until such time as the materials are delivered to the customer at the site for final use;
- limit the time that tyre-derived rubber materials can be stored at such an interim location to a maximum of 12 months; and
- limit the volume of tyre-derived rubber material that can be stored at such an interim location to a maximum of 5,000 tonnes.

8.4.7 The TAG concluded that, if such provisions are placed in a Quality Protocol, there should be recognition that the use of interim storage facilities would bring a positive benefit to the tyre recycling industry (provided an operator can meet the conditions).

8.5 Since this technical report was finalised by the TAG, the Environment Agency has considered these risks further.

8.5.1 Research suggests that the concentration of leachates drops after approximately 30 days exposure to the environment. Due to this, the Environment Agency has suggested that in order for tyre-derived rubber materials to cease to be waste, producers should undertake washing or weathering.

8.5.2 The project team suggest that this is written into the Quality Protocol, and wider industry are asked their views at consultation.

9. Findings and recommendations

9.1 Findings

9.1.1 The TAG's findings are summarised below.

- The assessment was limited to the production of tyre-derived rubber materials from used tyres using ambient and cryogenic processing techniques.
- A sustainable market exists in the UK for tyre-derived rubber materials. Material produced to the specifications contained within PAS 107 has 'certainty of use'.
- The regulatory controls that currently apply to the processing, storage and use of tyre-derived rubber materials to be the Environmental Protection Act 1990, Waste Management Licensing Regulations 1994 (as amended), Environmental Protection (Duty of Care) Regulations 1991 (as amended) and Water Resources Act 1991.
- The EU REACH Regulation 2006 has the potential to apply to tyre-derived rubber materials should a Quality Protocol be endorsed and the material no longer be defined as a waste. The TAG did not assess fully the volume and complexity of work required to meet the requirements of the REACH Regulation. However, this legislation could affect the UK manufacturers of tyre-derived rubber materials.
- There are uncertainties surrounding the outcome of ongoing work at a European level by the European Tyre & Rubber Manufacturers Association (ETRMA)[14] and other key organisations to reclassify tyre-derived rubber materials as a non-waste under the current review of the waste framework directive.
- The processing operations associated with production of tyre-derived rubber materials to meet the requirements of PAS 107 are outlined in Section 4 of this report. Tyre-derived rubber materials manufactured from used tyres can meet the quality specifications defined in Section 6 of this report and require no further processing prior to use.
- At present, there is no single organisation that could effectively administer an independent material verification and certification scheme on behalf of all manufacturers of tyre-derived rubber materials. Thus there is an unquantified risk surrounding the lack of a suitable mechanism (which could be in place with publication of a Quality Protocol) to verify a manufacturer's claim that their operations are in accordance with the Quality Protocol.
- It is possible the use of tyre-derived rubber materials in certain applications could lead to a potential negative environmental impact in some aquatic receptors. TAG members agreed that the measures proposed in Section 8 of this report would be suitable in mitigating such risks.
- On the basis of the risk assessment outlined in Section 8 of this report and provided the recommended mitigation measures are adopted, the risks of the identified hazards from the use of tyre-derived rubber materials are considered to be low in the following applications:
  - landfill engineering;
  - civil engineering (non-road) applications;
  - civil engineering (road) applications;
  - sports, leisure and safety surfaces applications; and
  - consumer/industrial applications.

9.2 Recommendations

9.2.1 The TAG recommends that:

- a Quality Protocol be developed for tyre-derived rubber materials based upon the findings of this technical report;
- the uncertainty surrounding implications of REACH and current activity at a European level should be raised at the consultation stage and wider industry views sought; and
- the identification of an independent body to administer an accreditation and certification scheme for UK manufacturers of tyre-derived rubber materials against a Quality Protocol should be raised as a consultation question to illicit industry and other stakeholder responses.

14 http://www.etrma.org

9.2.2 In addition to developing of a Quality Protocol, the TAG recommended that:

- the results of testing tyre-derived rubber materials against German DIN standards are reviewed with a view to assessing their potential use as an industry benchmark which could be incorporated into the Quality Protocol at a later date; and
- cryogenic processing is added to the scope of PAS 107 at the next PAS review.

9.2.3 Since this technical report was signed off by the TAG, the Environment Agency has recommended that the Quality Protocol should include:

- washing or weathering of the tyre-derived materials as a requirement to enable tyre-derived rubber materials to cease to be waste; and
- the time length for weathering should be 30 days but wider industry should be asked for their views on this at consultation.

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Other useful information sources:

Topic	Source
End-of-life vehicle and tyre recycling information factsheet	Waste Online http://www.wasteonline.org.uk/resources/InformationSheets/vehicle.htm
Zinc contaminants factsheet	Environment Bureau of Investigation http://www.eprf.ca/ebi/contaminants/zinc.html
Directive 2005/69/EC of the European Parliament and of the Council of 16 November 2005 amending for the 27th time Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations (polycyclic aromatic hydrocarbons in extender oils and tyres).	Official Journal of the European Union, L323, 51-54 (9.12.2005). Available from: http://eur-lex.europa.eu/LexUriServ/site/en/oj/2005l_323/l_32320051209en00510054.pdf [Accessed 25 July 2007].

Appendix A Technical Advisory Group (TAG) membership

Organisation	Representative	Type of member
British Tyre Manufacturers Association (BTMA)	John Dorken	Attending
Charles Lawrence Group	Roger Hicks	Correspondence
	John Bramwell	Correspondence
Credential Automotive	Steve Patterson	Correspondence
Department of Trade and Industry (now BERR)	Paul Hallett	Attending
Environment Agency	Suzanne Laidlaw	Attending
	Michelle Steer	Attending
	Dominic O'Neil	Attending
	Kathryn Harriss	Correspondence
	Rebecca Favager	Correspondence
	Clare McCallen	Correspondence
	Keith Lawton	Attending
Michelin Tyres	Geoff Holmes	Correspondence
Murfitts Industries	Barry Stocker	Attending
National Industrial Symbiosis Programme (NISP)	Dr Adrian Murphy	Correspondence
Scottish Environment Protection Agency (SEPA)	John Harris	Correspondence
Tyre Recovery Association (TRA)	Peter Taylor	Attending
Waste & Resources Action Programme (WRAP)	Steve Waite	Attending
	Sarah Clayton	Attending
Veolia Environmental Services	Sabrina Rubio	Attending

Appendix B: Terms of reference

1. Mission statement

To produce a technical report, recognised by (and produced with the support of) industry that defines when tyres (crumb and shred) have been reprocessed to such a level that they are considered to be fully recovered and no longer subject to the requirements of the regulatory waste regime.

If this is not achievable, the technical report will provide guidance to business that will:

- define when tyres (crumb and shred) are recovered to a state where the Environment Agency considers that their use is acceptable in accordance with its low risk regulatory principles; or
- confirm to the business community what legal obligations remain to control the reuse of the treated waste material.

2. Desired outcomes/outputs

The Technical Advisory Group (TAG) will produce a technical report that will identify and establish:

- where in the supply chain material has been recovered;
- whether material specifications exist and whether the material can be sold against that specification;
- what the potential impacts are to human health and the environment, and what mitigation methods may be used to maintain or reduce those impacts;
- the costs and benefits of the different end uses (with the aid of the project's economist); and
- a standard terminology.

3. Limitations

- The Environment Agency must be satisfied with the TAG's determination of the point at which tyres (crumb and shred) have been fully recovered.
- If the point of full recovery of tyres (crumb and shred) cannot be defined or agreed, the TAG will refer this matter to the Environment Agency for it to produce guidance on when waste regulatory controls apply.
- Where specifications and standards do not exist and are required, financial or time implications may result in delays in the TAG's work.

Appendix C: Market analysis for tyre-derived rubber materials

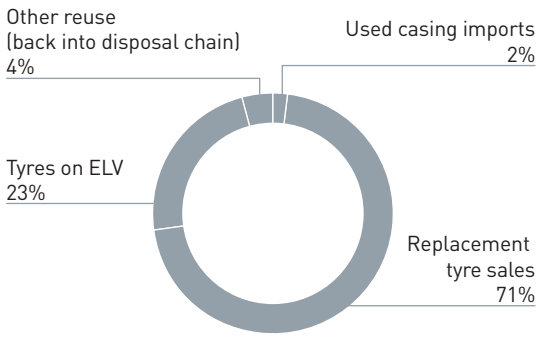
1. Introduction

WRAP established a three-year tyres programme[15] in April 2005 to break down barriers to the collection, segregation and reprocessing of waste tyres and to develop alternative end uses and markets for the recovered material. One of the main drivers for this programme was the introduction and transposition of the EU Landfill Directive,[16] which banned the landfilling of whole tyres from 2003 and shredded tyres from 2006. The programme has funded a number of market analysis studies and reported upon a number of market trials that seek to utilise the rubber material recovered from used tyres. Many of the findings published by WRAP have been used in the development of this market analysis.

2. Used tyre arisings

Used tyres are a significant waste stream in the UK with arisings of 486,578 tonnes in 2005 (figures from the DTI[17], now BERR). Figure C1 shows the quantities derived from different sources.

Figure C1 Used tyre arisings in the UK, 2005 (486,578 tonnes)



Source: WRAP (http://www.wrap.org.uk/construction/tyres/dti_used_tyre_statistics/2005_dti_tyre.html)

Table C1 provides a breakdown in tonnes of tyre arisings in 2005 by source. Analysis suggests that used tyre arisings fluctuate year by year but, between 2004 and 2005, they showed a growth of 2.38 per cent. Arisings of used tyres are expected to continue to increase at a rate consistent with the growth in vehicles in the UK, currently estimated at 1.3 per cent per year (WRAP 2006d). A more detailed analysis of used tyre arisings is provided by WRAP (2006a).

15 See http://www.wrap.org.uk/construction/tyres/index.html

16 For the Landfill Directive 1999/31/EC, see http://ec.europa.eu/environment/waste/landfill_index.htm The Directive is implemented in England and Wales via the Landfill (England and Wales) Regulations 2002 (as amended).

17 As part of its national statistics and analysis functions, DTI (now BERR) gathers data on a number of sectors including the arisings and recovery of used tyres in the UK.

Table C1 Sources of used tyres in the UK, 2005 (tonnes)		
Source	Vehicle type	Total
Tyres on end-of-life vehicles (ELVs)* (23%):		110,909
Car	77,958	
Van and light truck	11,405	
Truck and bus	21,546	
Other reuse (back into disposal chain) (4%)		20,000
Used casing imports (2%)		10,830
Replacement tyre sales (71%):		344,839
Car	175,898	
4x4	18,630	
Van and light truck	27,405	
Truck and bus	122,905	
Total used tyres arisings:		**486,578**
Car	**284,686**	
4x4	**18,630**	
Van and light truck	**38,810**	
Truck and bus	**144,451**	

Source: DTI (now BERR).
* The End-of-Life Vehicle Directive applies to cars and vans, not vehicles over 3.5 tonnes.

3. Collection of used tyres

The collection of used vehicle tyres is made through a nationwide network of tyre distributors, vehicle dealer networks, contracted vehicle maintenance companies, end-of-life vehicle processors, and vehicle servicing and repair outlets. Under the End-of-Life Vehicle (ELV) Directive, car manufacturers are obliged to set up networks of authorised treatment facilities to take in used cars at no cost to the consumer. In addition, there are independent facilities which are not contracted to vehicle manufacturers.

It has been estimated that at present there are around 100 specialist waste collectors of used tyres in the UK recycled tyre market. Collectors of used tyres are paid to take the tyres away . They in turn are charged a lower gate fee by recyclers.[18]

Collected used tyres are generally taken to a centralised facility (often located within the main zones for used tyre production in the UK, e.g. the West Midlands). Such facilities may slice the tyre into several pieces making its onward transportation more efficient by increasing the volume: mass ratio. These tyre slices (in the category >300mm) may be used directly for landfill engineering or processed further (potentially in a separate facility) for finer grade materials.

The major tyre collection companies and recyclers appear to influence the market significantly as their networks and relationships with recovery outlets pre-dispose the used tyres they handle to a certain route. A list of the numerous recovery and collection agents is available at: http://www.letsrecycle.com/equipment/tyre_recyclers.jsp

18 http://www.letsrecycle.com/equipment/tyre_recyclers.jsp

4. Tyre-derived rubber material production and capacity

The scope of the Quality Protocol incorporates both material recovery (shred/crumb) and shredded used tyres in landfill engineering. The market analysis conducted for this technical report is focused on production and use of these materials alone. The analysis does not consider:

- the use of whole tyres;
- combustion of tyres as an alternative fuel source;
- pyrolysis or de-vulcanisation technologies for recovering rubber compounds from waste tyres.

The production of tyre-derived rubber materials by ambient and cryogenic processing is covered by the scope of this technical report. Process descriptions for these two methods are given in Section 4.

Information collected by WRAP suggests that the number of recyclers in the UK could be in the region of[19]:

- 20 installations carrying out shredding only;
- 20 installations carrying out shredding and crumbing;
- 8 installations carrying out crumbing only.

In 2004, shredding capacity in the UK was estimated to be (WRAP 2006a):

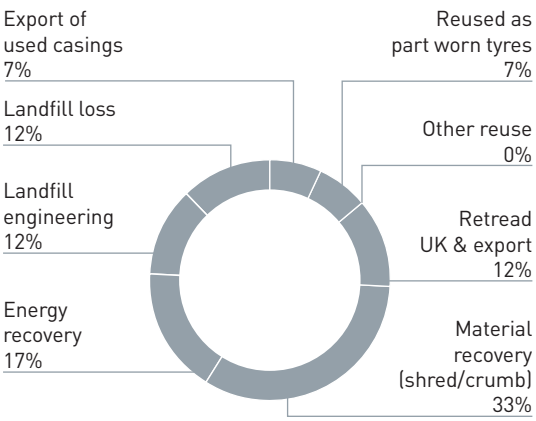
- major companies combined – around 400,000 tonnes per year; and
- smaller companies (some with mobile shredding equipment) – estimated 80,000 tonnes per year.

WRAP (2006a) states that the UK shredding processing sector has sufficient capacity to handle the kinds of increases that are likely in the near future (based on the historic growth in arisings). Additional crumbing capacity is expected in 2007 with the establishment of a plant with the capacity to process 30,000 tyres annually.

5. Use of tyre-derived rubber materials

Used tyre market assessment figures gathered by the DTI (now BERR) (figures for 2005) indicate that approximately 162,500 tonnes of used tyres are processed for material recovery (i.e. to give tyre-derived rubber materials) per year.

Figure C2 Used tyre arisings in the UK, 2005 (486,578 tonnes)



Source: WRAP (http://www.wrap.org.uk/construction/tyres/dti_used_tyre_statistics/2005_dti_tyre.html)

19 From a list of tyre processors supplied by WRAP.

The important markets for tyre-derived rubber materials covered by the Quality Protocol are listed in Table C2.[20] The tonnages show the end destinations of used tyres arisings. They do not take account of any removal of steel or fibre.

The most significant end markets in terms of tonnage are:
- landfill engineering; and
- sports, recreation and safety surfaces.

The different possible end uses of tyre-derived rubber materials is in a stage of infancy with many new uses for these products being trialled on a small scale.

Table C2 Key market sectors, tonnages and applications for tyre-derived rubber materials covered by the Quality Protocol

Market sector	Applications
Landfill engineering	Shredded used tyres can be used as a stabilisation and/or drainage layer in landfill construction. The substitutes include stone. Shred is cheaper and has the same performance.
Civil engineering (non-road)	Construction products – can include uses such as drainage filler and alternative to traditional aggregates in block applications and railway crossing matting. Recycled tyres perform as well as aggregate but are cheaper.
Civil engineering (road)	Road repair and maintenance – can include use of granulated rubber in modified asphalt and shred as roadway base layers. The alternative is to use aggregate stone. The performance is equivalent but recycled tyres are considerably cheaper.
Sports, recreation and safety surfaces	Loose surfaces – including equestrian ménages, bridleways, play surfaces such as artificial turf pitches, and pathways including cycle and footpaths. Bound rubber sports surfaces and safety surfacing for playgrounds. Equestrian (steel removed) – the price and performance of tyre shred are comparable to its substitutes of wood fibre, silica sand and grass. Sports surfaces and playground surfaces – competes with plastics, both of which are more expensive but are available in more colours. Some surface providers use virgin rubber or alternatives on the top layer (having used tyre-derived crumb as the base layer) to benefit from the greater choice of colours.
Consumer and industry	Moulded rubber products – includes carpet underlay, rubber blocks, composite slates, internal construction board and items of street furniture.

6. International trade in tyre-derived rubber materials

Generally only whole tyres are exported, including whole tyres still attached to vehicles. Exports accounted for 6.9 per cent of total tyre waste arisings in 2004 (WRAP 2006a). The extent of tyre-derived rubber materials exports is not known but is considered by the TAG to be insignificant.

20 Estimated figures for 2006 derived from DTI (now BERR) figures for 2005 with assumptions regarding the consequences of the ban on disposal of shred to landfill.

7. Potential market growth or decline

Material recovery (shred, crumb and granulate) tonnage is expected to increase at 5 per cent per year (WRAP 2006a). The key markets in this sector – namely equestrian and sports/play surfacing and carpet underlay – are probably saturated.[21] However, new and potentially high volume applications such as artificial turf should continue to grow and the momentum provided by the WRAP tyres programme is expected to encourage the introduction of new end applications for used tyres.

However, there is potential for significant demand changes in the overall used tyre end markets in the future. Scenarios presented in WRAP (2006d) consider the potential consequences of collapses in demand for used tyre material in certain end markets.

There is potential in some end applications for demand to be affected by customer perceptions of the human health and environmental risks associated with the use of used tyres. Examples include the perceived risks associated with leachates from tyre-derived rubber and claims that tyre-derived rubber surfaces could have implications for human health. Although there may be no evidence to support these claims, there may be a perceived risk.[22]

21 Communication with DTI (now BERR).
22 Communication with Oakdene Hollins Ltd (1 May 2007).

Appendix D Definitions

Term	Description
Ambient recycling	The processing of used tyres into rubber crumb and shred at room temperature without the addition of heat or cooling. The process generally involves chopping, shredding and grinding of the rubber tyres.
Aquatic habitats	Any habitat that is within a body of water. This includes surface waters such as pools, ponds, streams, rivers, lakes, seas and estuaries.
BREW	Business Resource Efficiency and Waste – a programme set up and administered by central government. It is funded via the Landfill Tax and is currently used to support environmental initiatives and projects seeking to maximise resource efficiency and minimise waste within England and Wales.
Cryogenic recycling	The processing of tyres using liquid nitrogen to freeze the tyres prior to shattering the rubber into smaller fragments. Widely used in both the USA and Europe, the UK has only one currently operational cryogenic processing facility in south Wales.
Controlled waste	Controlled waste is household, commercial and industrial waste. Controlled waste is defined in section 30 of the Control of Pollution Act 1974, section 75 of the 1990 Act and the Controlled Waste Regulations 1992 (as amended). Paragraphs 9(2) and 10(3) to Schedule 4 of the Waste Management Licensing Regulations 1994 provide that any reference to 'waste' in Part I of the 1974 Act or Part II of the 1990 Act includes a reference to Directive waste.
Duty of Care	The Duty of Care is set out in section 34 of the Environmental Protection Act 1990 and associated regulations. It applies to anyone who is the holder of controlled waste. Persons concerned with controlled waste must ensure that the waste: ■ is managed properly; ■ is recovered or disposed of safely; ■ does not cause harm to human health or pollution of the environment; and ■ is transferred only to someone who is authorised to receive it. The duty applies to any person who produces, imports, carries, keeps, treats or disposes of controlled waste or, as a broker, has control of such waste.
Environment Agency	The Environment Agency is the leading public body for protecting and improving the environment in England and Wales. Its job is to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world
Flora and fauna	Refers to all life (plants and animals) within a given habitat.

continues overleaf

Term	Description
PAS (107)	PAS documents are a series of publicly available specifications produced by the British Standard Institution (BSI) on behalf of other organisations. PAS 107 was produced for WRAP and is concerned with the processing of used tyres into crumb and shred for use as a recovered material.
Quality Protocol	A Quality Protocol sets out criteria for the production of a product from a specific waste type. Compliance with these criteria is considered sufficient to ensure that the recovered product may be used without risk to the environment or harm to human health, and therefore without the need for waste regulatory control. In addition, the Quality Protocol indicates how compliance may be demonstrated and points to best practice for the use of the recovered product.
REACH Regulation	This Regulation aims to control and limit the risk to both human health and the environment from the use of chemical substances and preparations in materials that are available to purchase on the open European market. Its full title is 'REGULATION (EC) No. 1907/2006 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH), establishing a European Chemicals Agency, amending Directive 1999/45/EC and repealing Council Regulation (EEC) No 793/93 and Commission Regulation (EC) No 1488/94 as well as Council Directive 76/769/EEC and Commission Directives 91/155/EEC, 93/67/EEC, 93/105/EC and 2000/21/EC'.
TAG	Technical Advisory Group. The TAG is a group of representative experts from industry, trade bodies, publicly-funded and regulatory authorities. The role of the TAG is to input its expertise into discussions regarding the technical, economic and environmental feasibility of developing and implementing the Quality Protocol.
Terrestrial habitats	Any habitat that is situated on the land surface. This includes mountains, plains, forests, fields, woodland and shorelines.
Tyre-derived rubber materials	For the purposes of this technical report, tyre-derived rubber materials are classified as used tyres subject to size reduction measures (ambient and cryogenic) to produce rubber cuts, shreds, chips, crumb, granulate and powder between the sizes of <150µm and 300mm.
Waste carrier	A person who transports controlled waste, within the UK, including journeys into and out of the UK.
Waste carriers registration	The Waste Framework Directive requires that establishments and undertakings that collect or transport waste on a professional basis, or which arrange for the disposal or recovery of waste (dealers or brokers), must be registered. This is implemented in UK legislation by the Control of Pollution (Amendment) Act 1989. Persons who carry waste as part of their business are required to be registered with the Environment Agency/SEPA/Environment and Heritage Service (as appropriate).

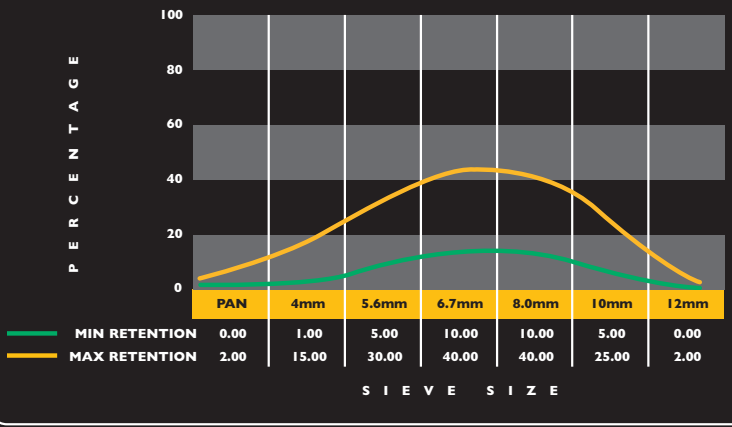
continues overleaf

Term	Description
Waste management licence	A Waste Management Licence (WML) is a licence issued by the Environment Agency/SEPA/Environment and Heritage Service (as appropriate) for a person(s) or company to undertake an activity involving the deposit, keeping, treating or disposal of a controlled waste (as defined in the Waste Framework Directive). In certain circumstances, however, exemption from licensing is available. Exemptions must be registered.
WRAP	WRAP (Waste & Resources Action Programme) works in partnership to encourage and enable businesses and consumers to be more efficient in their use of materials and recycle more things more often. This helps to minimise landfill, reduce carbon emissions and improve our environment.

Appendix E Example Material Safety Data Sheet (MSDS)

Product Code:	**CT4010**
Description:	**Tyre rubber granulate 4-10mm**
Total polymer content (natural and synthetic rubbers):	**56% minimum**
Acetone extract:	**5-20%**
Carbon black:	**25-35%**
Ash at 550°C	**15% maximum**
Sulphur:	**1-3%**
Hardness:	**60-79 IRHD**
Bulk density (uncompacted):	**495 kg/m³**

CT4010 Sieve analysis



Applications:	Sports Surfaces	Playgrounds	Equestrian	Rubber Mouldings
	✗	✓ ✓ ✓	✓	✗

✓ ✓ ✓ = Preferred use ✓ = Occasional use ✗ = Unsuitable

IMPORTANT NOTES:

Material fully conforms to the European standard CEN Workshop Agreement CWA 14243:2002. For safety information covering this and other grades of tyre derived granules, see details overleaf.

This material specification is given in good faith. However, the base material is a waste stream product and its composition cannot be guaranteed. Customers should carry out tests to ensure the material meets their application and, where necessary, is compatible with their particular chemical binders

The Company maintains a policy of continuous research and development to improve products and reserves the right to alter specifications without notice. Customers should check with the Company that they have the latest information.

All measurements on this data sheet are nominal.

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Safety Data
Tyre Rubber Granulate

Charles Lawrence International Ltd

Product Code: **CT4010**

Size: **4-10mm**

1. **PRODUCT DESCRIPTION** - Rubber granulate for industrial applications.
2. **COMPOSITION** - Granulated vulcanised rubber particles.
3. **HAZARDS** - This product is not classified as dangerous according to the CHIP regulations (Chemicals Hazard Information and Packaging Regulations 1994 - as amended).
4. **FIRST AID**
   *Eye Contact - Contact lenses should be removed. Irrigate copiously with clean fresh water for at least 10 minutes holding the eyelids apart and seek medical advice.
   Skin Contact - Wash skin thoroughly with soap and water and use a proprietary skin cleaner.
   Indigestion - If accidentally swallowed obtain immediate attention.
   *Inhalation - Remove to fresh air.
   Other - In all cases of doubt or when symptoms persist, seek medical attention.
   These items relate primarily to 'fines'
5. **FIRE FIGHTING**
   Extinguishing Media - Recommended: alcohol-resistant foam, CO^2 powder, water spray/mist.
   Run Off - Should not be allowed into drains, sewers or water courses.
   Fire and Explosion Hazards - Possibility of dust explosion if ignition of the particles suspended in air occurs in an enclosed space. As the product contains combustible organic components, fire will produce dense black smoke containing hazardous products of combustion.
   Protective Measures - Appropriate self-contained breathing apparatus may be required.
6. **ACCIDENTAL RELEASE**
   Personnel Precautions - Exclude sources of ignition and ventilate area. Exclude all non-essential personnel. Avoid breathing 'fines'.
   Recovery - Avoid dry brushing as dust clouds or static can be created.
7. **STORAGE & HANDLING**
   Storage - Smoking, eating and drinking should be prohibited in areas of storage and use.
   General - Good house keeping standards and regular safe removal of waste materials will minimise risk of spontaneous combustion and other fire hazards. The Manual Handling Regulations may apply to the handling of this product.
   Handling - Precautions should be taken to prevent the formation of dusts in concentrations above Flammable, Explosives or Occupational Exposure Limits. Avoid inhalation of dusts.
8. **EXPOSURE CONTROLS / PERSONAL PROTECTION**
   Occupational Exposure Limits - Inhalable dust: 8-hour TWA - 10mg/m^2.
   Respirable dust: 8-hour TWA - 5mg/m^2. Type OES.
   Engineering Measures - Provide adequate ventilation. Where natural ventilation is inadequate, use of local exhaust ventilation and good general extraction may be necessary.
   Personal Protective Equipment - Where engineering measures are not sufficient to maintain concentration of particulate below the relevant OEL's, suitable respiratory protection should be worn.
   Eye - Eye protection designed to protect against ingress should be worn as necessary.
   Other - Cotton/synthetic overalls or coveralls are normally suitable.
9. **PHYSICAL/CHEMICAL** - Granules with slight odour. Solubility - defined as immiscible.
10. **STABILITY / REACTIVITY** -
    Stability - Stable under the recommended storage and handling conditions.
    Materials to Avoid - Keep away from oxidising agents and strongly alkaline and acidic materials to prevent the possibility of exothermic reaction.
    Hazardous Decomposition - In a fire, hazardous decomposition products such as smoke, carbon monoxide and oxides of nitrogen may be produced.
11. **TOXICOLOGICAL** - There is no data available for this product.
12. **ECOLOGICAL** - The product is non-degrading. Do not allow into drains, sewers or water courses.
13. **DISPOSAL** - Wastes should be disposed of in accordance with the EPA Regulations. Do not incinerate.
14. **REGULATIONS**
    Applicable Regulations - The information contained in this safety data sheet does not constitute the users own assessment of workplace risks as required by other health and safety legislation.
15. **OTHER INFORMATION** - The information contained in this safety data sheet is provided in accordance with the requirements of the Chemicals (Hazard Information and Packaging) Regulations. Any queries or requests for more detailed information on specific applications or health and safety matters applied to this product should be obtained from our technical department. Please note it is the customer's responsibility to be aware of, and to comply with, the Environmental Protection Act 1990 and appropriate regulations, in particular section 34 of the Duty of Care.

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recycle