End-Of-Life Tyres (EoL)

Modern vehicle tyres are complex structures which contain various types of rubber alongside many different compounds and minerals which are carefully combined to produce properties which are optimal for durability, strength, grip, quietness and low rolling resistance. These materials require energy and resources to produce, and there's an increasing interest in recovering these resources once the tyre is no longer safely usable as a tyre (End-of-life). The complexity of the tyre material makes recovery challenging, but there are several viable options for reuse, recycling and the recovery of energy. In the UK alone around 50 million tyres (480,000 tonnes) reach the end of their usable life each year.

Composition

Each of the materials used in the construction of a vehicle tyre has a vital purpose. The major components used in a standard vehicle tyre and the relative proportions are[1]:

Rubber & Elastomers (~47%) – this is the biggest component in tyres and comprises a mixture of natural compounds from rubber plantations and synthetic rubber compounds from fossil feedstocks. Aviation and truck tyres contain a greater proportion of natural rubbers to improve mechanical strength.

Carbon black / Silica (~21.5%) – these materials are added to tyres as a reinforcement and filler. Carbon black gives most tyres their characteristic black colour and helps protect tyres from UV damage from sunlight, dissipates heat across the tyre and increases durability and strength.

Sulphur (~1%) – is added during vulcanization to improve crosslinking between rubber molecules and improve the mechanical properties of rubber for use in tyres.

Clays and heavy metals (~7.5%) – clay is used to fill and reinforce rubber in tyres alongside zinc oxide which promotes crosslinking in rubber, increasing strength and stability. Heavy metals such as Lead (Pb), Asenic (As) and Cadmium (Cd) can be present in tyres and are toxic. These heavy metals can leach from tyres into ground water and if the tyres are combusted, gas treatment is required to collect these toxic molecules which are often present in gas emissions.

Textiles (~5.5%) – Various different fibres such as nylon (polyamide) have been used in tyre. In most modern tyres fossil derived polyester (PET) is the preferred option. It is likely that non-fossil derived materials will be used in tyres in coming years as manufacturers work to reduce the environmental footprint from manufacture of tyres.

Metal (~16.5%) – Steel is used in the body of the tyre to reinforce the rubber and is readily recyclable once removed from tyres.

Current Fate

Placing most types of EoL tyres into landfill has been banned in Europe and the UK since 2006[2], and policy measures are being used successfully around the world to reduce tyre stockpiling. Stockpiling of tyres is damaging to the environment due to the leaching of toxic compounds into soil and water and presents a severe fire risk if large numbers of tyres are collected in one location. Tyres are flammable and once ignited can release significant amounts of energy along with multiple toxic compounds

[1] WRAP (UK)
[2] EU Waste Landfill directive

including carbon monoxide, dioxins, hydrogen cyanide, PCBs, PAHs, particulates and carcinogens. Fires in large heaps of tyres are extremely challenging to handle once they ignite, large tyre piles can burn for months or years, producing toxic smoke[3].

In the UK only around 15% of car tyres are reused or retreaded to extend the life of the tyre, however truck and aviation tyres, are regularly retreaded[4].

There are a large number of options for recycling tyres for secondary uses. These include creating rubber crumb for sports pitches; adding powdered rubber to bitumen to create rubberized asphalt; using rubber crumb to create products such as bollards or energy absorbent flooring; using whole tyres for landfill engineering/silage clamps/as impact protection for boats on waterways. As with landfill of tyres there is the potential for the leaching of toxic compounds or loss of microfibers into the environment. The benefit for many of these options is that the carbon in the tyres can be retained within the secondary materials. In the UK around 37% of tyres end up recycled into secondary products or materials.

Around 17% of UK tyres are used as a fuel in cement kilns as they provide a concentrated source of energy which has a lower carbon footprint than fossil alternatives such as coal. Whole tyres are often used in this way as steel is a useful ingredient in the production of clinker from cement furnaces.

Approximately 29% of UK EoL tyres are exported, namely for recycling or energy recovery, but as the tyres are not directly traced post-export, it is challenging to know exactly how and where these materials are processed. The high energy density of tyres means that in most cases these tyres will be combusted to provide energy or used in often poorly regulated pyrolysis plants to produce carbon black or fuel oil. Combustion of tyres in poorly managed conditions causes both environmental harm and damage to human health.

Pyrolysis recovery

Another alternative option which is gaining traction is the use of state-of-the-art tyre pyrolysis in the UK and Europe for recycling or energy recovery under controlled conditions and with regulated gas treatment systems. Heating of tyres, in the absence of oxygen, breaks down many of the constituent materials in the tyre. Various products can be collected from the process depending on the operating conditions and design. In general, there are three main outputs from tyre pyrolysis.

Tyre Pyrolysis oil (TPO) is a complex oil formed primarily through breakdown of the rubber and elastomer components of the tyre, but also through other components such as the textiles. The produced oil typically contains 40-50% biogenic carbon from a concentration of the proportion of natural rubber used in the tyres. This oil may be used in a similar way to crude oil which is used to create fuels and chemicals. The biogenic (plant derived) proportion of the oil is eligible for double counting under the UK renewable transport fuel obligation (RTFO) system for production of renewable fuels such as petrol, diesel or sustainable aviation fuel (SAF). TPO can be converted into drop in fuels through traditional refinery infrastructure. Hydrocarbon gases are produced by decomposition of some carbon materials into small molecules, these will often be combusted as part of the pyrolysis process to provide heat for the reactor.

Many of the other constituents of the EoL tyres including the carbon black, silica, textiles, clay and remaining steel will leave the reactor as a char material. This material can be further processed to produce an ash/char material, an activated carbon portion and recovered carbon black (rCB) which is a possible alternative to virgin carbon black. Production of virgin carbon black (CB) is highly energy

[3] https://www.theguardian.com/uk-news/2014/jan/17/tyre-fire-yorkshire-recycling-plant-space-satellite-video-pictures
[4] DEFRA used tyres working groups

intensive and causes significant levels of greenhouse gases. rCB may be used as a substitute to virgin CB with lower environmental impacts.

Pros & Cons

In terms of the waste hierarchy, it is better to reuse and recycle products and materials rather than using a process to recover the energy contained in the material. In this case it is valuable to continue developing new processes using end-of-life tyres as a raw material. Using rubber in road surfaces presents a fantastic opportunity to sequester carbon whilst increasing the durability of the UK road network. As there is a risk of metal leaching or microfiber pollution with any secondary use of tyres it is important for these products to be processed and formulated in a way which minimizes the risk to human health and the environment.

Pyrolysis provides a method by which tyres can be converted into new feedstocks which contributes to a circular use of material. As a number of these pyrolysis products contribute lower environmental impacts compared to those they can be substituted for, this presents an opportunity to promote a net benefit for the environment.

However, it must also be recognised that combustion and pyrolysis of tyres, without exhaust gas mitigation, is extremely environmentally damaging, both in terms of toxic airborne emissions and through production of acid emissions, and therefore should be prohibited. UK tyre waste should be traceable and handled according to all the principles of environmental regulations, which the UK and Europe have worked hard to establish [5-6]. Export of waste without oversight of the handling should no longer be an option.

Does pyrolysis present a holy grail for treatment of tyre waste?

No.

But it does provide an opportunity to process tyres into low emission recovered carbon black (rCB) and to produce renewable fuels or chemicals, through TPO. Crucially, it provides the opportunity to end poor waste export practices and take responsibility for the waste we produce. To find ways, not just to dispose of waste, but to develop circular ways of reusing the materials we previously treated as waste.

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[5] https://commonslibrary.parliament.uk/research-briefings/cbp-9600/

[6] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal_en