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**Technical matters: technical guidelines on environmentally sound management: revised technical guidelines on environmentally sound management of used tyres**

# Revised technical guidelines on environmentally sound management of used tyres

**Attached is the revised technical guidelines on environmentally sound management of used tyres as prepared by Brazil.**

**November 30, 2008.**

# Guidelines on environmentally sound management of used tyres

**Table of Contents**[1]



[1] UNEP/CHW.9/CRP.6

## Definitions of terms

| | |
|---|---|
| ***Ambient size reduction*** | Mechanical size reduction at or above ordinary room temperature. |
| ***Bale*** | Tyres which are compressed and secured. |
| ***Baling*** | A method of volume reduction whereby tyres are compressed into bales. |
| ***Bead*** | The part of the tyre that is made of high tensile steel wires wrapped in woven textile which are held by the plies, anchoring the part of the tyre which is shaped to fit the rim. |
| ***Buffings*** | Vulcanized rubber obtained from abrading a tyre during the process of removing the tread and/or sidewalls. |
| ***Chips*** | Mechanically fragmented, ripped or torn post-consumer tyres resulting in irregularly shaped post-consumer tyre pieces of approximately 10mm to 50mm in size. |
| ***Civil engineering applications*** | Use of whole, baled, cut, shredded, chipped, granulated or powdered tyres in construction projects. |
| ***Cryogenic size reduction*** | Technology at very low temperature using liquid nitrogen or commercial refrigerants to embrittle the rubber which is then processed to reduce it to a desired size. |
| ***Cuts*** | Mechanically fragmented, ripped or torn tyres resulting in irregularly formed pieces >300mm. |
| ***Devulcanizates*** | The product of devulcanization which results in the reduction of cross-links. |
| ***Devulcanization*** | The treatment of rubber that results in the reduction of cross-links. |
| ***End-of-life tyre*** | A tyre which has suffered permanent damage to its structure and is no longer suitable for retreading. |
| ***Fine powders*** | The result of processing rubber to achieve finely dispersed particles of <500mm including surface modified powders |
| ***Fines (carbon products)*** | Agglomerates, pellets or pellet fragments which pass through different standardized sieves. |
| ***Granulate*** | The result of processing rubber to reduce it in size into finely dispersed particles between approximately 1mm and 10mm. |
| ***Mixed car/truck tyres*** | An undefined inconsistent mix of car, truck and often utility tyres. |
| ***Other tyre*** | Includes tyres used by off-road agricultural vehicles, aircraft, among others |
| ***Particle size*** | The size of individual granules or grains of material after processing expressed as a range of distribution of sizes. |
| ***Post-consumer tyre*** | A tyre which has been permanently removed from a vehicle without the possibility of being remounted for further road-use. |
| ***Powder*** | The result of processing rubber to achieve finely dispersed particles of under 1mm. |
| ***Purity*** | Freedom from foreign matter. |

| | |
|---|---|
| ***Pyrolysis*** | The thermal decomposition of rubber in the absence of oxygen which chemically breaks it into oil, gas, and char. |
| ***Rubber reclaim*** | Rubber produced by treating a vulcanization in a manner to bring back some of its original characteristics. The reclaimed rubber has inferior qualities when compared to the original rubber |
| ***Scrap tyre*** | The same as waste tyre. |
| ***Shred*** | The result of mechanical processes by which tyres are fragmented, ripped or torn into irregular pieces of -50mm to -300mm in any dimension. |
| ***Shredding*** | Any mechanical process by which tyres are fragmented, ripped or torn into irregular pieces of 50mm to 300mm in any dimension. |
| ***Sidewall*** | The outermost rubber to which the tread is vulcanized. |
| ***Surface modification*** | The result of treating the surface of granulates or powders to impart specific properties to the particle. |
| ***Toxicity Characteristics Leaching Procedure (TCLP)*** | A test used in the United States to determine the leaching levels of specified metals and organics. |
| ***Tyre recycling*** | Any process by which post-consumer tyres or materials derived from post-consumer tyres is converted back into the original material. |
| ***Whole tyre*** | An untreated tyre of which the principal parts are the casing, the cord, the bead and the tread which consist of elastomers, carbon black and silica, metal and fabric. |
| ***Whole tyre applications*** | Use of whole tyres without physical or chemical transformation to create such projects as artificial reefs, sound barriers, temporary roads, stabilization, etc. |

# I. INTRODUCTION

## A. Background

As part of the efforts to reduce the transboundary movement of hazardous wastes and other wastes, a document entitled "Technical Guidelines on the Identification and Management of Used Tyres" (hereinafter referred to as "the Guidelines") was prepared, in response to the difficulties in identifying and managing used tyres, which can have impacts on human health and the environment.

The Guidelines were adopted by Decision V/26 of the fifth meeting of the Conference of Parties in December 1999 and the first version was published in October 2000. This same version was again issued in November 2002.

In the seven years that followed the publication of the Guidelines, additional knowledge and experiences with regard to waste tyres were developed in many countries, addressing technological, economic, and environmental factors that were broader than in the original version. Therefore, Decision VIII/17 of the eight meeting of the Conference of the Parties in November – December 2006 considered it appropriate to revise and update the content of the Guidelines.

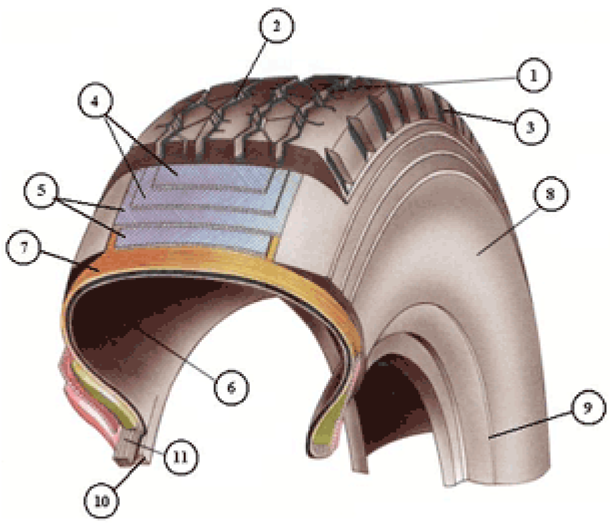
The content of the revised Guidelines has the same purpose as the original guidelines, *i.e.*, to assist national authorities in their environmentally sound management of used tyres within their national territories.

## B. General properties of tyres

### 1. Structure - Tyre Components and Definitions of Technical Terms

Tyres are made up of various components, which include several parts, types of steel and rubber compounds. The main components in a tyre structure, as well as the technical terms used for consumers to be able to identify its characteristics, are shown in Figure 1 below:

**Figure 1 – Components of a tyre**




**Notes:**

**1. The most common types of tyre structure are diagonal (Cross-ply), bias-belted and radial.**

**2. Almost 80 percent of all tyres sold are radial tyres.**

**3. The sidewall of a tyre contains the information, which varies according to the national applicable legislation and manufacturer, that is necessary for users to purchase tyres that are appropriate to their needs.**

**“Tread” (1)** means the part of a pneumatic-tyre that is designed to come into contact with the ground.

**“Tread groove” (2)** means the space between the adjacent ribs or blocks in the tread pattern.

**“Sidewall” (3)** means the part of a pneumatic-tyre between the tread and the area designed to be covered by the rim flange.

**“Ply” (4, 5)** means a layer of "rubber" coated parallel cords. In the radial tyre, it has the purpose of stabilizing the tyre.

**“Cord” (6)** means the strands forming the fabric of the plies in the pneumatic-tyre.

**“Carcass” (7)** means that structural part of a pneumatic-tyre other than the tread and outermost "rubber" of the sidewalls which, when inflated, supports the load.

**“Section width” (8)** means the linear distance between the outside of the sidewalls of an inflated pneumatic-tyre, when fitted to the specified measuring rim, but excluding elevations due to labeling (marking), decoration or protective bands or ribs.

**“Belt” (9)** applies to a radial ply or bias belted tyre and means a layer or layers of material or materials underneath the tread, laid substantially in the direction of the centre line of the tread to restrict the carcass in a circumferential direction.

**“Bead” (10)** means the part of a pneumatic tyre that is of such shape and structure as to fit the rim and hold the tyre onto it.

**“Chafer” (11)** means material in the bead area to protect the carcass against chafing or abrasion by the wheel rim.

## 2. Tyre Composition

The components of a new tyre is shown in Table 1, and the materials used in its manufacturing are shown in Table 2.

**Table 1 - Main components of Car and Truck tyres**

(In %)

| Material | Automobile (%) | Trucks (%) |
|---|---|---|
| Rubber/Elastomers* | 45 | 42 |
| Carbon black and silica | 23 | 24 |
| Metal | 16 | 25 |
| Textile | 6 | |
| Zinc oxide | 1 | 2 |
| Sulphur | 1 | 1 |
| Additives | 8 | |

***Source: Automobile tyres: ETRMA- LCA[2] and personal communication from tyre manufacturers for truck tyre***

Truck tyres contain more natural rubber as a proportion, relative to synthetic rubber, than do car tyres, because of different service conditions.

**Table 2 – Materials Used in the Manufacture of Tyres**

| Material | Source | Application |
|---|---|---|

[2] Lifecycle assessment of an average European cartyre. Préconsult for ETRMA, 2001.

| | | |
|---|---|---|
| Natural Rubber | Natural rubber is predominantly obtained from the sap of the *Hevea brasiliensis* tree. | Generally Natural rubber currently accounts for about 30% to 40% of the total elastomeric part in a car tyre and 60% to 80% of a truck tyre. |
| Synthetic Rubber | All synthetic rubbers are made from petrochemicals | Generally synthetic rubber accounts for about 60% to 70% of the total elastomeric part in a car tyre and about 20% to 40% of a truck tyre. |
| Steel cord and bead wire including the coating materials and activators, brass /tin/zinc. | The steel is premium grade and is only manufactured in a few plants around the world due to its high quality requirements. | Steel is used to provide rigidity and strength to the tyres. |
| Reinforcing fabrics | Polyester, rayon or nylon | Used for structural strength and of the carcasses of car tyres. |
| Carbon black, amorphous silica | Carbon black is derived from oil stock.<br>Amorphous silica is obtained from silicium mineral and sodium carbonate. It may have natural or synthetic origin. | Carbon black and silica provide durability and resistance against wear and tear. |
| Zinc oxide | Zinc is a mined mineral or also derived from recycled zinc, which then undergoes a production process to produce zincoxide. | Zinc oxide is added essentially as vulcanization activator. After vulcanization it is present as bound zinc in tyres. |
| Sulphur (including compounds) | A mined mineral or extracted from gas or oil. | Main actor or vulcanization. |
| Other additives and solvents age resistors, processing aids, accelerators, vulcanizing agents, softeners and fillers | Synthetic or natural source. | The other additives are used in the various rubber compounds to modify handling manufacturing and end-product properties. |
| Recycled rubber | Recovered from used tyres or other rubber products. | Used in some rubber compounds in the manufacture of 'new' rubber products and retread materials. |

Source: *Adapted from "A National Approach to Waste Tyres",2001 and ETRMA, 2001*.

## 3. Physical Properties

Tyres vary in weight depending on their composition and use. Table 3 contains information on the three most common categories.

**Table 3 – Average Weight of tyres by type**

| Type of tyre | Average weight (kg) | Units / ton |
|---|---|---|
| Passenger car | 6.5 -10 | 154 |
| Utility (Including 4 x 4) | 11.0 | 91 |
| Truck | 52.5 | 19 |

*Source: Hylands and Shulman, 2003*

Tyres have excellent combustion properties as a function of their high carbon content.

Their net calorific value is between 32 and 34 MJ/kg (Mega Joules /Kilogram).

Table 4 contains information on the energy content and the CO2 emissions from various fuels.

**Table 4 – Energy Content and $CO_2$ Emissions from Fuels**

| Fuel | Energy (GJ/t) | Emissions | |
|---|---|---|---|
| | | $kgCO_2/t$ | $kgCO_2/GJ$ |
| Tyres | 32.0 | 2,720 | 85 |
| Carbon | 27.0 | 2,430 | 90 |
| Pet coke | 32.4 | 3,240 | 100 |
| Diesel oil | 46.0 | 3,220 | 70 |
| Natural gas | 39.0 | 1,989 | 51 |
| Wood | 10.2 | 1,122 | 110 |

*Source: World Business Council on Sustainable Development (WBCSD),2005 – CO2 Emission Factors of Fuels,*

Tyres do not undergo spontaneous combustion and are therefore not classified as flammable (characteristics H4.1 to 4.3 of Annex III of the Convention). Work carried out by the Building Research Establishment in England[3] using tyre bales showed the following results:

(a) The minimum temperature for ignition was 182ºC; if maintaining the temperatiure at 182°C for 65,4 days;

(b) Short term self ignition will only occur after exposure to a temerature of 350°C for 5 minutes or to a temperature of 480°C for 1 minute.

However, it is worth highlighting that natural phenomenon (such as lightening, when tyres are not properly stored) and deliberate human acts (such as arson, air balloons, etc.) can cause conditions that are conducive to tyre combustion. A list of fires that occurred in waste tyre stockpiles is in Annex III.

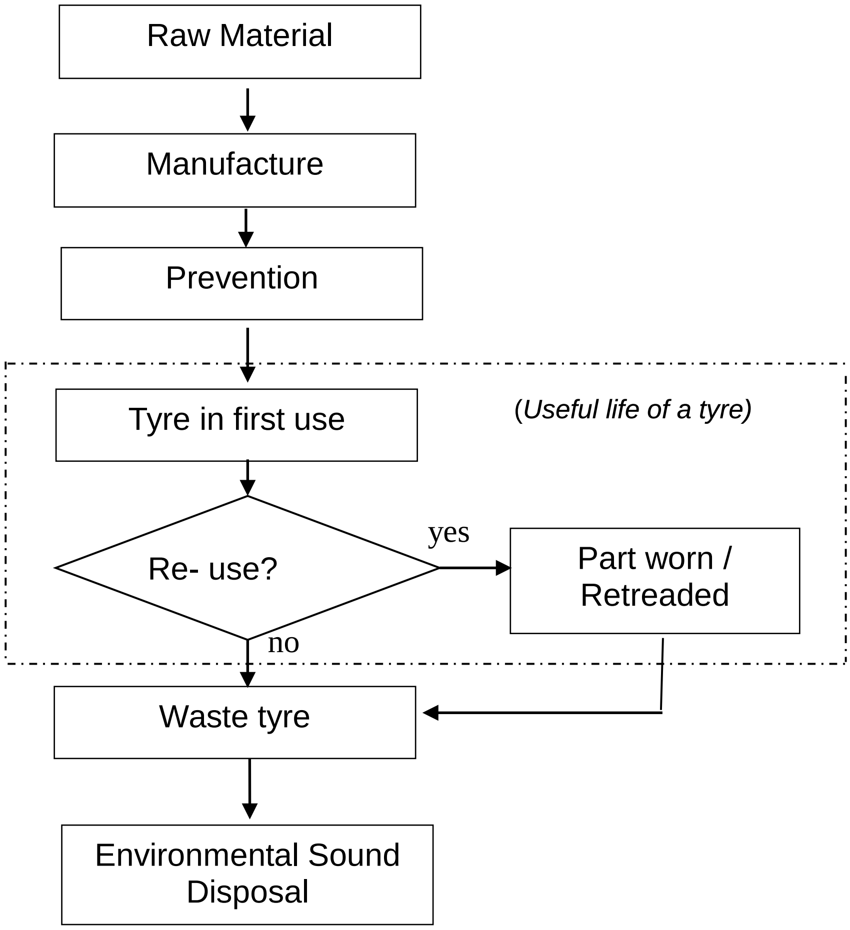
Once initiated tyre fires are difficult to control, as a result of the heat generated.

## C. Stages in the life of a tyre

The various stages in the life of a tyre, from when raw material is acquired through manufacture, use and final disposal are shown in Figure 2.

[3] HR Wallingford. "Sustainable Re-use of Tyres in Port, Coastal and River Engineering - Guidance for planning, implementation and maintenance." March 2005.

**Figure 2 – Stages in the Life of a tyre**




## 1. Used tyres

Some countries allow the commercialization of used tyres to be reused as partly worn for their original purpose. However, it is worth highlighting that there are risks involved in the purchase of a used tyre, which should be done with great care. Given that the manner in which the tyre was used is unknown, these tyres could have originated from vehicles involved in accidents, damaged by potholes and obstacles, used without the appropriate pressure calibration or incorrectly repaired.

Used (partly worn) tyres can be reused without further treatment. Sources of used tyres include:

(a) Tyres fitted to second-hand vehicles that are sold and from vehicles that are scrapped;

(b) Old (out of date) tyres that are used for less demanding applications such as on trailers; and

(c) Tyres that are exchanged for reasons other than that the tyres have reached the end of their life, such as fitting a set of high performance tyres or different wheels.

The United Kingdom has legislation about the sales and distribution of used tyres, as part of its “Motor Vehicle Tyres Safety Regulations” of 1994. The requirement for selling and distributing these tyres are as follows:

(a) The tyre may not have any cut in excess of 25 mm or 10% in its section width, measured in any direction on the outside portion of the tyre or deep enough to reach the ply or cord;

(b) The tyre may not have any external lump, bulge or tear caused by the separation or failure of its structure;

(c) The tyre may not have any of the ply or cord exposed either internally or externally;

(d) When inflated to the highest pressure at which it is designed to operate, the tyre may not exhibit any of the defects described above;

(e) The base of any groove that showed in the original tread pattern must be clearly visible; and

(f) The grooves of the original tread pattern must be at least 2 mm deep across the full breadth and around the entyre outer circumference of the tyre.

Currently, there are studies being made to equip tyres with electronic chips called Radio Frequency Identification Device (RFID) that record information about their conditions of use. If their efficiency can be proven, RFID may provide a means to identify the appropriate conditions for re-using used tyres.

## 2. Retreaded tyres

The term “retreading” refers to replacing the wearing surface of the tyre. Three different types of processes, i.e. top-capping, recapping and bead to bead are described:

(a) Top-capped tyres are those in which the tread is removed and replaced with a new arranged one;
(b) Re-capped tyres also have their tread removed, however in this case the new tread used is larger than in the re-topped tyre, as it covers part of the tyre’s sidewalls;
(c) Bead to bead tyres are those in which the tread is removed and the new one goes from the one side to the other, covering all of the lower part of the tyre and cover the sidewalls with a rubber layer.

In some cases, a criterion in tyre retreading is to control the number of times a tyre may be retreaded. According to United Nations regulations ECE 108 and ECE 109, which establish the requirements for approval of the production of retreaded tyres, passenger automobile tyres may be retreaded just once, while truck and aircrafts tyres, thanks to their stronger structure, may be retreaded more often, as long as the quality standards are satisfied**,** a limited number of times. In addition, the lifetime of an original tyre casing should be considered and must not exceed seven years.

To meet safety standards tyre retreading should only be carried out by qualified companies, and tyres should be certified to guarantee safety and quality standards for consumers. Therefore, it is important that consumers purchase retreaded tyres from companies that follow the rules that established retreading systems and have their tyres certified.

Environmental impacts of retreading tyres are generally positive. The impacts from retreading should be contrasted with impacts of manufacturing new tyres. Retreading a tyre consumes considerably less material and energy than that required for a new tyre, with a proportional decrease in other impacts. A number of authors have published data in broad terms about the energy and material savings from retreading. Retreading utilises a significant proportion of the rubber and all the fabric and steel in a tyre. The processing energy is reported to be lower than for a new tyre though the actual reduction varies depending on the type of retreading (whether hot or cold or remoulding). The estimates available for tyres indicate that retreading has significant potential to reduce overall energy and greenhouse emissions, as well as reduce the quantity of waste tyres that are produced[4].

Tyre retreading is beneficial to the environment from the perspective that it minimizes the generation of waste, because it increases the useful life of tyres, thereby postponing their final disposal. However, this reasoning is only valid if the tyre casings that serve as raw material for retreading are originated domestically. If imported, used tyres displace domestic suppliers of casings. Thus, tyres retreaded with imported casings will replace new tyres and tyres retreaded with domestically generated casings. Because tyres can only be retreaded a limited number of times, these imports can result in an increase in the overall volume of waste tyres the importing country will have to dispose of.

The main environmental impacts caused by the process of tyre retreading are shown in table 6.

**Table 5 – Environmental Impacts of Retreading**

| | |
|---|---|
| Energy and material use | As retreading extends the life of a tyre and utilizes much of the original materials and structure, the net result is a decrease in materials and energy used in comparison with new tyres.<br><br>The energy used to retread a tyre is approximately 400MJ compared to 970 MJ for manufacturing a new tyre. |
| Air emissions | The primary areas of concern are volatile organic compounds (VOCs) from solvents, bonding agents and rubber compounds during vulcanization. Odor may also be an issue in some areas. |
| Solid wastes | The process generates significant wastes. The rubber removed from used tyres before retreading is generally sold as rubber crumbs for other purposes. |

*Source: Adapted from A National Approach to Waste Tyres, 2001*

### 3. Waste tyres

A tyre that can no longer be used for the same purpose for which it was originally manufactured is referred to as waste tyre. A tyre that is characterized as being “waste” does not have the technical conditions necessary for retreading, but its material can be recovered by being cut, shredded or grounded and used in several applications, such as in footwear, sports surfaces, (carpets) etc. Waste tyres can also be used as Tyre-Derived Fuel (TDF) for energy recovery.

## D. Potential risks to health and the environment

The constituents of tyres do not make them exhibit hazardous properties. Therefore they are not intrinsicly hazardous. However, when not properly managed and disposed, tyres may present certain risks for public health and the environment. They are not biodegradable, given that the time they take to decompose is indeterminate. Used tyres are wastes that take up a lot of physical space, are difficult to compact, collect and eliminate. These aspects are shortly highlighted in this chapter. More detailed information about the public health aspects is given in Appendix I. The aspects of environmentally sound management when re-using, recycling or disposing of tyres are addressed in Chapter III.

[4] *National Approach to Waste Tyres, 200*

### 1. Risks to Public Health

Tyres are ideal sites for rodents and also breeding sites for mosquitoes that transmit dengue and yellow fever. This last issue is of relevance in particular for tropical and subtropical regions. The round shape of tyres, coupled with their impermeability enable them to hold water and other debris (e.g., decaying leaves) for long periods of time, turning them into perfect sites for the development of mosquito larva. These also breed in other man-made containers like earthenware jars, metal drums and concrete cisterns used for domestic water storage, as well as in discarded plastic food containers. It is known that tyres are a breeding site for mosquitoes.

Tyres specially facilitate the spread of two species of mosquitoes, *Aedes aegypti* and *Aedes albopictus*. These are the principal vectors of dengue and yellow fever diseases that afflict millions of people in tropical regions. In temperate regions, other species such as *Aedes triseriatus* and *Aedes atropalpus* are more predominant.

The movement of used tyres not only spreads mosquitoes that have a limited reach, but also contributes to the introduction of non-native species, which are often more difficult to control, increasing the risk of disease. The rapid geographic spreading of in particular *Aedes ablopictus* has been largely attributed to the international trade in used tyrs.

The Tiger mosquito was first introduced into the south-east U.S. in the late 1980s with the importation of used tires from Asia. It spread rapidly along north-south transportation routes aided by the movement of goods and people, and has displaced native species of mosquitoes in some areas. No human case of viral transmission due to *Aedes albopictus* has been documented in the U.S. or Canada to date. The Tiger mosquito has been found as far north as Chicago but it does not survive the winters in northern U.S. nor has it ever been identified in Canada.[5]

This evidence demonstrates conclusively that the accumulation of used and waste tyres, as well as their transport, poses a genuine risk of diseases that are transmitted by mosquitoes. Companies involved in transport and management should be aware of this issue and handle tyres in such a way that the spreading of such diseases is prevented or reduced. More information about these diseases and possible measures to be applied by companies is given in Appendix I.

The WHO publication: Dengue haemorrhogic fever: diagnosis, treatment, prevention and control[6] indicates in its chapter 5 on vector surveillance and control that the most effective means of vector control is environmental management. This includes planning, organization, carrying out and monitoring activities for the modification or manupulation of environmental factors with a view to preventing or reducing vector progpagation and human-vector-pathogen contact. One of the important factors influnecing the these contacts is the fact that in urban area's often waste is not collected but abandonned in the vacinity of housing areas. Moreover, used tyres are often used by the population for various purposes, including use to plant flowers, provide ballast on roofs of houses and manufacturing of toys for children. These uncolled tyres may then become breeding places for mosquitoes. Filling, covering or collecting tyres for recycling or disposal are mentioned as measures for vector surveillance and control in these cases. This stresses the importance of awareness raising and a good functioning collection and management system for tyres.

### 2. Environmental Risks

The aspects of impact on the environment of different technologies and methods to treat tyres as well as the environmentally sound management when disposing of tyres are dealt with in Chapter III, subsection E, of this guide. In this general chapter on potential

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[5] Health Canadá

[6] WHO, 2nd edition, 1997

environmental risks associated with tyres the more horizontal issues of ecotoxicity, leaching and emissions from uncontrolled buring and accidental fires are addressed.

**Ecotoxicity**

Studies were conducted in 1995 by the Pasteur Institute in Lille using rubber powder obtained from tyre carcasses with algae (*S. Capricornutum* and crustacean: *Daphnia magnia* and *Fish Brachydanio rerio*), according to ISO 8692, 6341 and 7346 regulations.Subsequently, in 1996, a supplemental study was conducted, i.e. "Determination of Acute Toxicity as per ISO11268/1 – Observing the effect of tyre powder rubber on a population of earthworm placed in a definite substratum," also at the Pasteur Institute in Lyon. The four tests did not indicate toxicity.

In 2003, tests conducted by Birkholz in California using rubber crumbs taken from a site were the tyre had been disposed showed toxicity to: bacteria, invertebrates, fish and green algae. After three months, new samples were tested, demonstrating a 59% reduction in the toxicity detected in previous tests.

**Leaching**

Water generated by tyre leachate may contaminate both soil and surface water and groundwater on the site and surrounding areas. Based on specialized literature and their own experience, the Ministry of the Environment of New Zealand[7] pointed out several factors that may affect the rate of leaching and/or the concentration of tyre leachate compounds in soil, surface water and groundwater.

Information about fieldwork conducted to study tyre leachate are included in Appendix II.

**Uncontrolled Open Air Burning**

Tyres are not subject to spontaneous combustion. However, in the event that a fire occurs, either by arson or due to accidental causes, the pile composition will affect the rate and direction of the fire. Fires occurring in piles of whole tyres tend to burn down into the middle of the pile where air pockets allow continued combustion. Fires occurring in piles of chipped or shredded tyres tend to spread over the surface of the pile.

**Fire Decomposition Products**

A wide variety of decomposition products is generated during the process of combustion, including:

(a) Ash (typically containing carbon, zinc oxide, titanium dioxide, silicon dioxides, cadmium, lead, and other heavy metals);
(b) Sulphur compounds;
(c) Polynuclear aromatic hydrocarbons – PAH’s;
(d) Aromatic oils;
(e) Carbon and nitrogen oxides;
(f) Particulates; and
(g) Various light-end aromatic hydrocarbons (such as toluene, xylene, benzene, etc).

Fire decomposition products are quite extensive and vary as a function of several factors, including:

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[7] Ministry for the Environment. “End-of-Life Tyre Management: Storage Options Final Report for the Ministry for the Environment.” MWH. July 2004.

(a) Type of tyre;
(b) Burn rate;
(c) Size of tyre piles;
(d) Temperature of the environment; and
(e) Humidity.

Some of the fire decomposition products, in particular those that are the result of incomplete combustion are POPs. The reduction or elimination of non-intentional emissions of such substances is regulated by Article 5 and Annex C of the Stockholm Convention.

In France, the SNCP had done a number of field experiments to determine the composition of smoke from fires of tyre in warehouses where tyres are stored, both with and without sprinkler installations[8]. The following composition of the smokes were found;

**Table 6 – Composition of smoke from fires of tyre**

| Component | Production in non-sprinkler installation (g/kg of tyre burned) | Production in installation with sprinkler (g/kg tyre burned) |
|---|---|---|
| CO2 | 1450 | 626 |
| CO | 35 | 42 |
| N2O | 0.9 | 0.75 |
| NO | 3.2 | 1.6 |
| SO2 | 15 | 4 |
| Cyanhydric acid | 4 | 0.6 |
| Hydrocholic acid | Not detected | 2 |
| Total unburned organics (including benzene, toluene, in tonuene equivalents) | 23 | 61 |
| Dust | 285 | 20 |
| Metals (total) including aluminium and Zinc >99% | 31.9 | 22.74 |
| Polycyclic Aromatique Hydrocarbons (total) | 0.0633 | 0.093 |
| PCB (total) | $2.66 \times 10^{-4}$ | $2.16 \times 10^{-5}$ |
| Dioxines / furanes (total | $6.44 \times 10^{-7}$ | $1.9 \times 10^{-7}$ |
| Components looked for but not detected (below analytiaue detection limit) | Foradehyde, Hydrochloric acid, Hydrobromic acid, Acroleine, Ammonium, Tin | Foradehyde, Hydrobromic acid, Acroleine, Ammonium, Tin |

Due to the lowering of the temperature fires controlled by sprinkler installations have

[8] Incendie dans un entrepôt de stockage de prneumatiques équipé d'une installation sprinkler. Impact environnemental sur l'air et sur l'eau. SNCP 2007.

higher emissions of CO and unburned organics. The other emissions are lower, in particular for dust, which is washed out of the smoke. The observed concentrations of PCB and dioxins/furans are normally comparable to those observed in ambient air. This may be different for large stockpiles of tyres or monolandfills for tyres.

**Potential Impacts of Uncontrolled Fires**

Uncontrolled tyre fires have major environmental impacts on air, water and soil.

**Air Pollution**

Open air tyre fires generate emissions of black smoke, carbon dioxide (that contribute to greenhouse effects), volatile organic compounds and hazardous air pollutants, such as polynuclear aromatic hydrocarbons (PAHs), dioxins, furans, hydrogen chloride, benzene, polychlorinated biphenyls (PCBs), arsenic, cadmium, nickel, zinc, mercury, chromium, and vanadium.[9]

Possible leachate of such pollutants with rainwater may also lead to soil and water contamination. It can occur through two different atmospheric processes known as wash out (small particles that cling together and are brought in by rainwater) and rain out (larger particles that are directly affected by rainfall).

**Water Pollution**

Tyre combustion causes pyrolysis of the rubber, resulting in oily decomposition waste. In addition to the problems caused by oil runoff, the waste may be carried by water, if water is used to put out the fire, or via percolation through the soil reaching the underground water or nearby streams. A million tyres consumed by fire generate about 200,000 liters of runoff oil. In addition to having a highly pollutant capacity, this oily waste is also flammable. Other combustion residues, such as zinc, cadmium and lead, can also be washed away by water. Depending on the situation, contaminants such as arsenic, benzene, mercury, copper, dioxins, PCBs and PAHs could also be present.

**Soil Pollution**

Residues that remain on the soil after a fire can have an impact in two different ways, i.e. immediate pollution caused by liquid decomposition products penetrating the soil, and gradual pollution caused by leaching of ash and other unburned residues. Both of them are caused mainly through rainfall and water infiltration at the site.

[9] Reisman, Joel. I. “Air Emissions from Scrap tyre Combustion.” United States National Risk Management Environmental Protection Research Laboratory. Agency Cincinnati, OH 45268. November 1997.

# II. RELEVANT PROVISIONS OF THE BASEL CONVENTION

## A. General provisions

The Basel Convention, which entered into force on 5 May 1992, stipulates that any transboundary movement of wastes (export, import, or transit) is permitted only when the movement itself and the disposal of the concerned hazardous or other wastes are environmentally sound.

In its Article 2 ("Definitions"), paragraph 1, the Basel Convention defines wastes as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law". In paragraph 4 of that Article, it defines disposal as "any operation specified in Annex IV" to the Convention. In paragraph 8, it defines the environmentally sound management (ESM) of hazardous wastes or other wastes as "taking all practicable steps to ensure that hazardous wastes or other wastes are managed in a manner which will protect human health and the environment against the adverse effects which may result from such wastes".

Article 4 ("General obligations"), paragraph 1, establishes the procedure by which Parties exercising their right to prohibit the import of hazardous wastes or other wastes for disposal shall inform the other Parties of their decision. Paragraph 1 (a) states: "Parties exercising their right to prohibit the import of hazardous or other wastes for disposal shall inform the other Parties of their decision pursuant to Article 13." Paragraph 1 (b) states: "Parties shall prohibit or shall not permit the export of hazardous or other wastes to the Parties which have prohibited the import of such waste when notified pursuant to subparagraph (a)."

Article 4, paragraphs 2 (a)–(d), contains key provisions of the Basel Convention pertaining to ESM, waste minimization, and waste disposal practices that mitigate adverse effects on human health and the environment:

"Each Party shall take appropriate measures to:

(a) Ensure that the generation of hazardous wastes and other wastes within it is reduced to a minimum, taking into account social, technological and economic aspects;
(b) Ensure the availability of adequate disposal facilities, for the environmentally sound management of hazardous wastes and other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal;
(c) Ensure that persons involved in the management of hazardous wastes or other wastes within it take such steps as are necessary to prevent pollution due to hazardous wastes and other wastes arising from such management and, if such pollution occurs, to minimize the consequences thereof for human health and the environment;
(d) Ensure that the transboundary movement of hazardous wastes and other wastes is reduced to the minimum consistent with the environmentally sound and efficient management of such wastes, and is conducted in a manner which will protect human health and the environment against the adverse effects which may result from such movement".
(e) Not allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic and/or political integration organization that are Parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner, according to criteria to be decided on by the Parties at their first meeting;

(g) Prevent the import of hazardous wastes and other wastes if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner.”

## B. Tyre Related Provisions

Article 1 (“Scope of the Convention”) defines the waste types subject to the Basel Convention. Subparagraph (a) of that Article sets forth a two-step process for determining whether a “waste” is a “hazardous waste” subject to the Convention: first, the waste must belong to any category contained in Annex I to the Convention (“Categories of wastes to be controlled”), and second, the waste must possess at least one of the characteristics listed in Annex III to the Convention (“List of hazardous characteristics”).

One important element of the Convention is that a Party is not bound by the definition of hazardous waste (and other residues) established by the Convention. Each Party is free to decide whether it considers a certain waste “hazardous”, for the purpose of the Convention, pursuant to its national legislation. In this case, the country needs to notify the Basel Secretariat about the content of its national legislation, which in turn notifies the other Parties to the Convention that the transboundary movement of such waste is prohibited.

Tyres cannot be identified under any category of waste streams in the first part of the Annex I of the Basel Convention (Y1-Y18). Tyres contain elements or compounds listed in Annex 1 of the Basel Convention. They are encased in the rubber compound or present as an alloying element and are shown in Table 5.

**Table 7 – Annex I constituents contained in tyres**

| **Basel Constituent** | **Chemical Name** | **Remarks** | **Content** (% weight) | **Content * ( Kg )** | **Applicability or Annex III** |
|---|---|---|---|---|---|
| Y22 | Copper Compounds | Alloying constituent of the metallic reinforcing material (Steel cord) | Approx. 0.02% | Approx. 0.14 g | Part of steel: in metallic non-dispersible form as listen in Annex IX entry B1010. Not exhibiting any annex III characteristics. |
| Y23 | Zinc Compounds | Zinc Oxide, retained in the rubber matrix | Approx. 1% | Approx. 70 g | Whole tyres do not present any of the characteristics H1 – H12 contained in Annex III of the Convention H13 is only assessed for leaching of Zinc which is not over thresholds . (see Chapter III) |
| Y26 | Cadmium | On trace levels, as Cadmium compounds attendant substance of the Zinc Oxide | Max. 0.001% | Max. 0.07 g | Not in a quantity identified as giving to the waste any of the characteristics contained in Annex III |
| Y3 1 | Lead<br>Lead Compounds | On trace levels, as attendant substance of the Zinc Oxide | Max. 0.005% | Max. 0.35 g | Not in a quantity identified as giving to the waste any of the characteristics contained in Annex III |
| Y34 | Acidic solutions or acids in solid form | Stearic acid, in solid form | Approx. 0.3 % | Approx. 21 g | As a natural fat has extremely low acidity and cannot be classified as an hazardous acid under the terms of Annex I Y34 |

| | | | | | |
|---|---|---|---|---|---|
| Y45 | Organohalogen compounds other than substances in Annex to the Basel Convention | Halogen butyl rubber | Content of Halogens Max. 0.10 % | Content of halogens Max. 7 g | Not having charcteristics pursuant to Annex III |

Wastes contained in Annex I of the Basel Convention are presumed to exhibit one or more Annex III hazard characteristics, which may include H11 “Toxic (delayed or chronic)”, H12 “Ecotoxic” and H6.1 “Poisonous (acute)”, unless, through “national tests”, they can be shown not to exhibit such characteristics. National tests may be useful for identifying a particular hazard characteristic listed in Annex III until such time as the hazardous characteristic is fully defined. Guidance papers for each Annex III hazard characteristic are currently being developed under the Basel Convention.

List A of Annex VIII of the Basel Convention describes wastes that are “characterized as hazardous under Article 1 paragraph 1 (a) of the Convention” although “Designation of a waste on Annex VIII does not preclude the use of Annex III (hazard characteristics) to demonstrate that a waste is not hazardous” (Annex I, paragraph (b)). List B of Annex IX lists wastes which “will not be wastes covered by Article 1, paragraph 1 (a), of this Convention unless they contain Annex I material to an extent causing them to exhibit an Annex III characteristic”.

The following Annex IX waste characteristic is applicable to tyres: B3140: Waste pneumatic tyres, excluding those destined for Annex IVA operations.

As stated in Article 1, paragraph 1 (b), “Wastes that are not covered under paragraph (a) but are defined as, or are considered to be, hazardous wastes by the domestic legislation of the Party of export, import or transit” are also subject to the Basel Convention.

# III. GUIDANCE ON ENVIRONMENTALLY SOUND MANAGEMENT (ESM)

## A. General Considerations

As noted above, ESM is defined under the Basel Convention in fairly general terms. In Article 4, paragraph 8, the Convention requires that “hazardous wastes or other wastes, to be exported, are managed in an environmentally sound manner in the State of import or elsewhere. Technical guidelines for the environmentally sound management of wastes subject to this Convention shall be decided by the Parties at their first meeting”. The present technical guidelines are intended to provide a more precise definition of ESM in the context of used tyres including appropriate treatment and disposal methods.

The Framework Document on Preparation of the Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention (1994) sets forth the principles used by countries in their strategies for waste management, among which the following should be highlighted:

- The source reduction principle: the generation of wastes should be minimized both in terms of quantity and potential for causing pollution. This can be achieved through appropriate processes and facilities;
- The integrated life cycle principle: substances and products should be managed in such a way that there is minimal environmental impact during their production, use, reuse and disposal;
- The precautionary principle: preventive measures should be taken, considering the costs and benefits, of action and inaction, when there is scientific basis, however limited, to believe that the emission of substances, wastes and energy into the environment could possibly result in injury to human health and the environment;
- The proximity principle: the disposal of hazardous wastes should occur as close as possible to their sources of origin, recognizing that the environmentally and economically sound management of some of these wastes could take place at disposal facilities located farther away from their sources of origin;
- The least transboundary movement principle: the transboundary movement of hazardous wastes should be reduced to a minimum that is consistent with environmentally sound and efficient management;
- The polluter-pays principle: potential polluters should take steps to avoid pollution, and those who pollute should pay to solve the problems created by pollution;
- The sovereignty principle: each country should take into consideration its political, social and economic conditions when establishing a national policy for waste management. For instance, countries may ban the importation of hazardous wastes pursuant to their environmental legislations;

In this document, “disposal” is considered to be any operation specified in Annex IV of the Basel Convention, which is also included in its text under Article 2 – “Definitions” – including sections A and B.

The document does not include the term “recycling” as a possible disposal operation, given that, in the case of tyres, it is not possible to transform the materials of a used tyre into new tyres due to the fact that, unlike paper, metals, plastics and glass, it is not possible to obtain materials from tyres that have properties that are appropriately similar to those of the original materials used in their production. The rubber material used in tyres has specific qualities that are quite complex, designed to optimize traction on dry and wet roads, ensure long useful life, low rolling resistance, comfortable handling with good response to steering, and good performance at a relatively low cost. Unfortunately, recycled products currently available do not improve on performance and are costlier. With regard to automobile tyres, there are effects that are particularly detrimental to durability and rolling resistance (associated with fuel consumption). Therefore the quantity of these post-consumer recycled materials must be necessarily very low.[10]

### 1. Basel Convention

Several key principles with respect to ESM of waste were articulated in the 1994 Framework Document on Preparation of Technical Guidelines for the Environmentally Sound Management of Wastes Subject to the Basel Convention.[11]

To achieve ESM of wastes, the Framework Document recommends that a number of legal, institutional and technical conditions (ESM criteria) be met, in particular that:

(a) A regulatory and enforcement infrastructure ensures compliance with applicable regulations;
(b) Sites or facilities are authorized and of an adequate standard of technology and pollution control to deal with hazardous wastes in the way proposed, in particular taking into account the level of technology and pollution control in the exporting country;
(c) Operators of sites or facilities at which hazardous wastes are managed are required, as appropriate, to monitor the effects of those activities;
(d) Appropriate action is taken in cases where monitoring gives indications that the management of hazardous wastes has resulted in unacceptable releases; and
(e) People involved in the management of hazardous wastes are capable and adequately trained in their capacity.

ESM is also the subject of the 1999 Basel Declaration on Environmentally Sound Management, adopted at the fifth meeting of the Conference of Parties to the Basel Convention. The Declaration calls on the Parties to enhance and strengthen their efforts and cooperation to achieve ESM, including through prevention, minimization, recycling, recovery and disposal of hazardous and other wastes subject to the Basel Convention, taking into account social, technological and economic concerns; and through further reduction of transboundary movements of hazardous and other wastes subject to the Basel Convention.

The Declaration states that a number of activities should be carried out in this context, including:

(a) Identification and quantification of the types of waste being produced nationally;
(b) Best practice approach to avoid or minimize the generation of hazardous wastes and reduce their toxicity, such as the use of cleaner production methods or approaches; and
(c) Provision of sites or facilities authorized as environmentally sound to manage wastes and, in particular, hazardous wastes.

Parties to the Basel Convention should examine national controls, standards and

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[10] California Environmental Protection Agency (US), "Integrated Waste Management Board, Increasing the Recycled Content in New Tyres 21" (2004) (quoting Bridgestone/Firestone Corporation)

[11] See Basel Convention 1994 in annex V, Bibliography.

procedures to ensure that they fully implement their Convention obligations including those which pertain to the transboundary movement and ESM of used tyres.

Implementing legislation should give governments the power to enact specific rules and regulations, inspect and enforce, and establish penalties for violations.

The legislation could define ESM and require adherence to ESM principles, ensuring that countries satisfy provisions for ESM of used tyres including their environmentally sound disposal as described in the present guidelines.

Hazardous wastes and other wastes should, as far as is compatible with their ESM, be disposed of in the country where they were generated. Transboundary movements of such wastes are permitted only under the following conditions:

(a) If conducted under conditions that do not endanger human health and the environment;
(b) If exports are managed in an environmentally sound manner in the country of import or elsewhere;
(c) If the country of export does not have the technical capacity and the necessary facilities to dispose of the wastes in question in an environmentally sound and efficient manner;
(d) If the wastes in question are required as a raw material for recycling or recovery industries in the country of import; or
(e) If the transboundary movements in question are in accordance with other criteria decided by the Parties.

According to article 6 to the Convention, any transboundary movements of hazardous and other wastes are subject to prior written notification from the exporting country and prior written consent from the importing and, if appropriate, transit countries. Parties shall prohibit the export of hazardous wastes and other wastes if the country of import prohibits the import of such wastes. The Basel Convention also requires that information regarding any proposed transboundary movement is provided using the accepted notification form and that the approved consignment is accompanied by a movement document from the point where the transboundary movement commences to the point of disposal.

Furthermore, hazardous wastes and other wastes subject to transboundary movements should be packaged, labelled and transported in conformity with international rules and standards.[12]

When transboundary movement of hazardous and other wastes to which consent of the countries concerned has been given cannot be completed, the country of export shall ensure that the wastes in question are taken back into the country of export for their disposal if alternative arrangements cannot be made. In the case of illegal traffic (as defined in Article 9, paragraph 1), the country of export shall ensure that the wastes in question are taken back into the country of export for their disposal or disposed of in accordance with the provisions of the Basel Convention.

No transboundary movements of hazardous wastes and other wastes are permitted between a Party and a non-Party to the Basel Convention unless a bilateral, multilateral or regional arrangement exists as required under Article 11 of the Basel Convention.

### 2. OECD – Core Performance Elements for the ESM of waste

12 In this connection, the United Nations Recommendations on the Transport of Dangerous Goods (Model Regulations) (UNECE, 2003a – see annex V, Bibliography) or later versions should be used.

The OECD adopted in May 2004 the recommendation of the council C(2004)100[13] on the ESM of wastes (OECD 2004). Waste management facilities, including recovery facilities, should, within the framework of laws, regulations and administrative practices in the countries in which they operate, and in consideration of applicable international agreements, principles, objectives and standards, take due account of the need to protect the environment, public health and safety, and generally conduct their activities in a manner contributing to the wider goals of sustainable development. In particular, taking into account the size of the enterprise, especially the situation of the small and medium size enterprises (SMEs), the type and amount of waste, the nature of the operation and domestic legislation, the following core performance would apply to waste management facilities:

1. The Facility Should Have an Applicable Environmental Management System (EMS) in Place;
2. The Facility Should Take Sufficient Measures to Safeguard Occupational and Environmental Health and Safety;
3. The Facility Should Have an Adequate Monitoring, Recording and Reporting Programme;
4. The Facility Should Have an Appropriate and Adequate Training Programme for the Personnel;
5. The Facility Should Have an Adequate Emergency Plan;
6. The Facility Should Have an Adequate Plan for Closure and After-care.

For further information, please refer to the guidance manual[14] for the implementation of the OECD recommendation on ESM of waste which include the core performance elements.

## B. Management approaches to used and waste tyres

Even though tyres are consumer goods that are currently indispensable and essential to any country's economy, inappropriate disposal can cause impacts on the environment and human health. Generating waste is unavoidable; therefore it is essential that sound management systems are implemented to minimize waste generation but also maximize the reuse and recycling, and the energy/material recovery of waste tyres.

### 1. General considerations

Processes for disposal may be overall grouped into the following categories, within the strategy addressed in item B:

(a) Reclaim / Devulcanization (Chemical);
(b) Pyrolysis (Thermal);
(c) Civil engineering;
(d) Consumer and Industrial products (including elastomers);
(e) Co-processing;
(f) Incineration.

The advantages and disadvantages of these processes and their applications are summarized in Annex 1.

All existing processes for disposing of used and scrap tyres generate environmental and

[13] OECD (2004): Draft Recommendation of The Council on the Environmentally Sound Management (ESM) of Waste. C(2004)100.

[14] OECD (2007); Guidance manual for the implementation of the OECD recommendation C92004)100 on environmentally sound management of waste.

health impacts, which cannot be totally eliminated, and should therefore be kept to a minimum.

### 1.1. Environmental Mangement Systems (EMS)

Tyres' structure, durability, and heat retaining capacity are a potential threat to the environment. This is the main reason why non generation measures should be employed whenever possible. The inadequate disposal of tyres, whether in open terrain or in water courses increases environmental risks.

For decades, in several countries, vast quantities of tyre waste have been dumped or stockpiled in the environment, at a substantial cost to public health, animals and plants. For a very long time, these tyres were simply piled and stored in gigantic heaps or dumped in landfills. Governments now realize, however, that these practices are not sustainable.

In addition to the visual impact, inadequate disposal can block water channels, creeks and storm water drains. Resulting changes in flow patterns can lead to erosion and the silting up of water flows due to the retention of solid wastes contributes to flooding.

Prone to heat retention and owing to their own open structure, piled tyres facilitate the occurrence of fires, by arson or due to accidental causes such as lightning, which once ignited, are difficult to control and put out, and can burn for months,[15] generating smoke and toxic oil contaminants that affect the soil, waterways and air.

In landfills, tyres occupy valuable space, do not biodegradade, and frequently rise to the surface, creating a new set of landfill management concerns. [16]

### 1.2. Pollution prevention and control

This section presents the technologies and their main environmental problems and suggestion to avoid them.

| Technology | Problems | Prevention and Control |
|---|---|---|
| Ambient/Cryogenic grinding | ➢ noise, dust | To be completed by the intersessional working group. |
| Devulcanization/Reclaim | ➢ liquid effluents;<br>➢ air emissions. | To be completed by the intersessional working group. |
| Pyrolysis | ➢ air emissions;<br>➢ hazardous residues;<br>➢ liquid effluents. | To be completed by the intersessional working group. |
| Civil Engineering | ➢ lechating;<br>➢ air emissions;<br>➢ ocuppational problems;<br>➢ fires. | To be completed by the intersessional working group. |
| Industrial and consumer products | ➢ generation of rubber residues. | To be completed by the intersessional working group. |

15 Health Protection Agency (UK), Chemical Hazard and Poisons Report 8 (2003) ("UK – Chemical Hazard Report").

16 Directive 1999/31/CE refer to the deposition of tyres in landfills and supports this paragraph.

| Technology | Problems | Prevention and Control |
|---|---|---|
| Co-processing | ➢ Toxic and above limit air emissions (including PCDD emissions). | ➢ The content of the fuel used and the contents of raw materials used in cement production;<br>➢ Monitoring and stabilization of critical process parameters, i.e. homogenous raw mix and fuel feed.<br>➢ Regular dosage and excess oxygen.<br>➢ Limit or avoid alternative raw material feed as part of raw-material-mix if it includes organic materials and fuel with low contents of sulphur, nitrogen, chlorine, metals and VOC.<br>➢ TDF can be used no more than 20% as supplementary fuel.<br>➢ Quick cooling of kiln exhaust gases to lower than 200°C in long wet and long dry kilns without preheating.<br>➢ No alternative fuel feed during start-up and shut down.<br>➢ Process control optimization, including computer-based automatic control systems;<br>➢ The use of modern fuel feed systems;<br>➢ Minimizing fuel energy by means of preheating and precalcination, to the extent possible.<br>➢ Preventive measures in non-expected shut down. |

## 2. National systems for managing used and waste tyres

Managing systems that are being used for this purpose include the following:

**Producer Responsibility-Based System**

The law defines the legal framework and assigns to producers (manufacturers and importers) the responsibility for organizing and processing waste tyres. A national operating company or association is created and producers contribute to a common fund that covers the cost of collecting and disposing of tyres. The trend is to attribute a greater weight to this system of collection.

The waste management resolution approved by the European Parliament emphasizes that an adequate implementation of the producer responsibility principle constitutes a powerful instrument for waste management. (Directive 75/442/CEE, revised 07/Feb /2007).

**Tax-Based System**

In this system, producers or consumers pay the government a tax. The State is then responsible for organizing a system to collect and dispose of tyres, which is implemented, for instance, through the hiring of operating companies that are remunerated with funds collected as a result of the tax levied.

The U.S. State agencies, for example, regulate waste tire management (not the federal government). Most states in the U.S. have a consumer tax on the sale of a tire. That tax supports the state management of waste tires. Some US states spend considerable funds to implement waste tyre programs, while a few states just rely on the free market system for support of the collection and eventual use in waste tyre applications.

**Free Market-Based System**

In a free market-based system, the legislation sets forth the goals to be achieved, but does not specify who is responsible for the process. In this way, all those involved in the chain are free to hire according to market conditions, while working in compliance with the legislation.

Table 8 has information about countries as their respective management systems for used and waste tyres.

**Table 8 – Systems for Managing the Collection and Sorting of tyre that are Adopted in Various Countries**

| Producer Responsibility | Tax-based System | Free Market System |
|---|---|---|
| **Europe** (Belgium, Finland, France, Greece, Hungary, Norway, the Netherlands, Poland, Portugal, Romania, Spain, Sweden, and the Czech Republic), **Turkey** | **Europe** (Denmark , Latvia, Slovak Republic) | **Europe** (Austria, Germany, Ireland, Switzerland, United Kingdom) |
| **Brazil** | **Canadá**, **United States** (most states) | **United States** (some states) |
| **Canada** (British Columbia) | | **Australia** |

### C. Waste prevention and minimisation

Following the waste management hierarchy established, priority should be given to preventing and reducing waste generation, which include thereduction in the wear and tear of tyres in order to increase their useful life, thereby reducing the rate of generated waste. To that end, calibration and maintenance guidelines and procedures recommended by tyre manufacturers should be followed.

The various challenges that both the developed and the developing countries continue to face with regard to waste tyres make it clear that the smaller the amount of tyres a country is required to manage, the better.

An instrument to minimise and prevent waste pneumatic tyres is the shift to other modes of transports not dependant on the use of tyres such as railways and waterway, especially in countries were such networks are developed.

Another way to increase the useful life of tyres is to use the retreading process. If tyres generated domestically are used as raw materials, retreading is beneficial to the environment and can be considered a key element in non generation strategies, because it increases the useful life of tyres, postponing their disposal as waste. Other measures to reduce the number of waste pneumatic tyres include the use of retreaded tyres in official vehicles and the periodical tenchical inspections that promote the retreadability of used tyres.

At the end of their life cycle, tyres can be transformed through physical, chemical or biological processes, into a new product or raw material to be used as input for applications other than their original use. However, before waste tyres can be used for other applications or be forwarded to disposal, intermediate procedures related to their collection, transportation, sorting, storage and size reduction should be appropriately implemented.

### D. Colection, transportation and storage

Collecting, transporting and sorting of tyres are important phases in the management process. Collecting tyres requires logistics and planning that take into account the diversity of points where these tyres are generated, in addition to the need to educate citizens about the benefits arising from their being delivered for disposal in a manner that is environmentally sound.

To give an used tyre an ESM, it is necessary to collect it on the place where it was generated and transport it to a place for storage. This is a crucial stage in the ESM of used tyres, since there is a large number of places in big cities where tyres have to be quickly collected. Nevertheless, destination of used tyres very often receive greater attention than collectio.

Transporting used tyres from the various sources of generation to facilities for sorting represents an additional burden in terms of costs, primarily in cases where distances between the points of collection and sorting are long, since tyres take up a lot of space within the trucks in which they are transported. Safety during transportation is another factor that needs to be taken into account, requiring that stockpiling and packaging rules be strictly followed.

Since collection is a logistic process, the optimisation has to be addressed either on a cost base or on an environmental base. Depending on economical and legal model various type of optimisation can be put in place. Two main ways of optimisation are:

- Collecting the maximum quantity of tyres in one run (that may include several stops);
- Collect in such a manner that manual handling is minimized.

When possible using special containers to collect tyres is often the best way of achieving both maximum the quantity of tyres per run and a drastic reduction of the manpower required.

Sorting is necessary to separate used tyres that can be retreaded, used tyres that can be used for other purposes and waste tyres. Sorting requires the availability of covered facilities and a specialized workforce.

Storage is also certainly a critical issue in the collecting process. If the management of the overall flow is well controlled, the storage should be more a stock in transit before the next step of the tyreprocessing than a permanent stock.

To store tyres without endangering human health or the environment the storage facility needs to meet certain requirements. These requirements are in most cases part of national regulations regarding such storages. Various recommandations are existing in the world. The aim is to prevent major risks by reducing quantity stored per unit and putting in place appropriate equipment (see for examples table 9).

As an example, some guidelines for this purpose are available in a joint publication issued by three entities, i.e. International Association of Fire Chiefs (IAFC), Rubber Manufacturers Association (RMA) and the National Fire Protection Association (NFPA) (2000) and MWH, 2004 (see footnote 28).

The following requirements shall be taken into account when choosing and operating a site for storing and stockpiling tyres:[17]

(a) Selecting an appropriate site;

(b) Preventing and minimizing the spread of fires, (e.g., by setting a minimum distance between two cells);

(c) Minimizing leachate production, (e.g., by covering tyre piles);

(d) Minimizing leachate contamination of the soil and underground water, (e.g., by having a compacted clay surface);

(e) In some contries, avoiding and controlling the breeding of mosquitoes and other vectors for diseases can also be relevant for for minimizing impacts on public health (see also section D and Appendice I).

Tables 9 and 10 and Figure 3 present information on the best practices for the design of

[17] Ministry for the Environment. “End-of-Life Tyre Management: Storage Options Final Report for the Ministry for the Environment.” MWH. July 2004

sites for the temporary storage and stockpiling recommended in this study. Table 9 also includes a comparative study (MWH 2004) of information provided by private associations and specialists with over 20 years of experience in the tyre reprocessing industry (MWH 2004).

Despite the fact that the study is inconclusive regarding storage time, it is recommended that this should be done only when necessary and for the shortest period of time possible.

**Table 9 – Best Practices for Storing Waste Tyres**

| Criteria | IAFC, RMA and NFPA Guidelines | Specialist * |
|---|---|---|
| Storage time | NR | NR |
| Tyre pile maximum dimensions | 6 m high<br>76 m long<br>15 m wide | 4.5 m high<br>60 m long<br>15 m wide |
| Pile slope | NR | $30_0$ slope if naturally piled<br>$90_0$ slope if laced in piles<br>(See Figure 3) |
| Clearance in stockpiling site | Edge of pile 15 m from perimeter fence<br>60 m radius from the pile should not have vegetation, debris and buildings | Edge of pile 15 m from perimeter fence |
| Fire breaks | 1-8m between piles | 15 m between piles at base |
| Site selection | Avoid wetlands, flood plains, ravines, canyons, sloped areas, graded surfaces, and power lines | NA |
| Ground surface/liner | Ideally flat site<br>Concrete or hard packed clay surface;<br>No asphalt or grass | Compacted area |
| Cover | MWH always recommends that tyre piles should be covered to prevent leaching | NR |
| Runoff | Collection and retention | Soil bund around pile to minimize runoff of water used in fighting fires |
| Ignition sources | No open air burning within 300 m<br>No welding or other heat generating devices within a 60 m radius | NA |
| Water supply | 75 l for 6hrs for tyres >1415 $m^3$ | NA |
| Other fire fighting resources | Foam, chemicals, fill dirt on site<br>Access to heavy equipment/materials | NA |
| Fuel-powered vehicles | Fire extinguisher on board | NA |
| Perimeter of facilities | Fences, > 3 m high with intruder controls | NA |
| Signals | Visible with regulations and hours | NA |
| Security | Qualified Personnel | NA |
| Emergency vehicle access routes | Well maintained and accessible at all times<br>Clearance width >18 m and height 4 m | NA |

| | | |
|---|---|---|
| Gates at access point | 6 m width at all times<br>Locked when closed | NA |

NR, no recommendations; NA, not asked
*Source: The Prevention and Management of Scrap Tire Fires" IAFC, STMC, NFTA, 2000*
* Specialist: Michael Playdon, Columbus McKinnon, February 2004

**Figure 3 shows the two most common ways of stockpiling tyres.**

**A: Banded B: Laced**

*Source: National Fire Protection Association, 2003 – Standard No. 230: Standard for the Fire Protection of Storage*

**Table 10 – Minimum Clearance between Piles**

| Exposed face Dimension (m) | Height of tyre Piles (m) | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2.4** | **3** | **3.7** | **4.3** | **4.9** | **5.5** | **6.1** |
| 7.6 | 17.1 | 18.9 | 20.4 | 22.3 | 23.5 | 25.0 | 25.9 |
| 15.2 | 22.9 | 25.6 | 28.3 | 30.5 | 32.6 | 34.4 | 36.0 |
| 30.5 | 30.5 | 35.4 | 39.0 | 41.8 | 44.5 | 47.2 | 50.0 |
| 45.7 | 30.5 | 35.4 | 39.0 | 41.8 | 44.5 | 47.2 | 50.0 |
| 61.0 | 30.5 | 35.4 | 39.0 | 41.8 | 44.5 | 47.2 | 50.0 |
| 76.2 | 30.5 | 35.4 | 39.0 | 41.8 | 44.5 | 47.2 | 50.0 |

*Source: National Fire Protection Association, 2003 – Standard No. 230: Standard for the Fire Protection of Storage*

## E. Environmentally sound disposal including recovery, recycling and reuse

The tecnologies here presented illustrates the most important environmental sound disposal options and applications in use or under development at this moment. Its respect the hierarchy: reduction, reuse, recycling, recovery and reclaim.

### (a) Ambient/Cryogenic Grinding

Used whole tyres can be used for other purposes, but most procedures utilize grinded tyres to make the use of rubber viable for their various applications. A tyre may be shredded or grinded at different grades, depending on its final application.

Figure 4 shows the schematic of a typical ambient waste tyre recycling plant, with its various steps and respective control system. The process is called ambient, because all size reduction steps take place at or near ambient temperatures, i.e. no cooling is applied to make the rubber brittle.

**Figure 4 – Schematic of an Ambient Waste Tyre Processing Plant**

Source: *Reschner (2006)*

In this plant layout, tyres undergo several operations:

(a) Tyres are first processed into chips of 2” (50 mm) in size in a preliminary shredder;

(b) The tyre chips then enter a granulator - in this processing step the chips are reduced to a size of smaller than 3/8” (10 mm);

(c) Steel is removed magnetically and the fiber fraction is removed by a combination of shaking screens and wind sifters;

(d) There are successive grinding steps to obtain the appropriate size, usually between 10 to 30 mesh (0.6 mm to 2 mm).

Ambient grinding can be operated safely and economically if the bulk of the rubber output needs to be relatively coarse material, i.e., down to approximately 20 mesh (o.8 mm). (Reschner *2006*).

Ambient grinding generates noise, dust and the consume of energy is intense (120 – 125 Kwh /metric ton). To guarantee the worker’s health and safety the machinery should be equipped with appropriate ventilation systems, fire protection systems, and emergency cut-offs on all equipment. The use of steel reinforced boots, gloves, eye and ear protection, as well as protective headgear should be mandatory. An appropriate site for storing grinded rubber should also be provided. This site should be protected from sunlight.

These measures will have an impact on the costs associated with operating and maintaining the system. With regard to preventive and safety measures for workers, collective protection measures should be adopted first, followed by individual protection.

The cryogenic tyre grinding process is called “cryogenic” because whole tyres or tyre chips are cooled down to a temperature of below -80o C, using liquid nitrogen. Below this temperature, rubber becomes nearly as brittle as glass and size reduction can be accomplished by crushing and grinding. This type of size reduction facilitates grinding and steel and fiber liberation, resulting in a cleaner end product.

The main drawback is the cost, because the process begins with tyre chips. In order words, in addition to the costs for the initial grinding, there are those associated with the high cost of liquid nitrogen.  The process also requires operational safety procedures to prevent work-related accidents.

The cryogenic process is illustrated in Figure 5.

**Figure 5 – Cryogenic Waste Tyre Grinding**

Source: *Reschner (2006)*

The cryogenic process is the following:

(a) Tyres are first processed into chips of 2” (50 mm) in size in a preliminary shredder;
(b) The 2” (50 mm) tyre chips are cooled in a continuously operating freezing tunnel to below –120° C;
(c) In the hammer mill, chips are shattered into a wide range of particle sizes;
(d) Steel and fiber are eliminated;
(e) The material is dried;
(f) Then classified into defined particle sizes;
(g) Fine mesh rubber powder is required.

Table 11 shows a comparison between parameters from the ambient grinding system and the cryogenic process.

**Table 11 – Comparison - Ambient Grinding vs. Cryogenic Grinding**

| Parameter | Ambient | Cryogenic |
|---|---|---|
| Operating Temperature | Ambient, max. 120° C | below – 80° C |
| Size Reduction Principle | cutting, tearing, shearing | breaking cryogenically embrittled rubber pieces |
| Particle Morphology | spongy and rough, high specific surface | even and smooth, low specific surface |
| Particle Size Distribution | relatively narrow particle size distribution, only limited size | wide particle size distribution (ranging 10 mm to 0.2 mm) in |

| | | |
|---|---|---|
| | reduction per grinding step | just one processing step |
| LN2 Consumption | N/A | 0.5 – 1.0 kgLN2 per kg tyre input |

Source: *Reschner (2006)*

Table 12 shows the nomenclature used to classify tyre products as a function of their size.

**Table 12 – Post Consumer Tyre Treatment – Size of Materials**

| Material size | Minimum (mm) | Maximum (mm) |
|---|---|---|
| Powder | 0 | 1 |
| Granulate | 1 | 10 |
| Buffings | 0 | 40 |
| Chips | 10 | 50 |
| Shreds (small) | 40 | 75 |
| Shreds (large) | 75 | 300 |
| Cut | 300 | ½ tyre |

*Source: Report SR 669 HR Wallingford 2005*

### (b) Reclaim / Devulcanization

Reclaiming is a procedure in which tyre rubber is converted – using mechanical processes, thermal energy and chemicals – into a state in which it can be mixed, processed, and vulcanized again. The principle of the process is devulcanization, which consists of the cleavage of intermolecular bonds of the chemical network, such as carbon-sulfur (C-S) and/or sulfur-sulfur (S-S) bonds. These confer durability, elasticity and solvent resistance to tyres. Reclaimed rubber is used to manufacture products that have limited demand and applications, because it has mechanical properties that are worse then those of the original.[18]

Devulcanization involves two different steps, i.e. size reduction and cleaving of the chemical bonds, which can be achieved through four processes with costs and technologies that are quite differentiated, i.e. chemical, ultra-sound, microwave, and biological.[19]

The chemical devulcanization process is a batch process where reduced particles (between 10 and 30 mesh) are mixed with reagents in a reactor at a temperature of approximately 180º C and a pressure of 15 bars. Once the reaction is over, the product is filtered and dried to remove undesirable chemical components, and packaged for commercialization.

In the ultrassonic process, reduced rubber particles (between 10 and 30 mesh) are loaded into a hopper and subsequently fed into an extruder. The extruder mechanically pushes and pulls the rubber. This mechanical action serves to heat the rubber particles and soften the rubber. As the softened rubber is transported through the extruder cavity, the rubber is exposed to ultrasonic energy. The combination of heat, pressure, and mechanical mastication is sufficient to achieve varying degrees of devulcanization.

The microwave process applies thermal energy very quickly and uniformly on the waste rubber. However, any vulcanized rubber used in the microwave process must be

18 *Tyres in the Environment*, at § 4.4 ("The properties of the recycled rubber are not as good as the virgin material, as it has already been vulcanized. The use of recycled rubber limits the properties of the final product .. [and causes] a one-percent reduction in the properties of the final product for every one-percent of substitution ...").

19 Calrecovery Inc. – "Evaluation of Waste Tyre Devulcanization Technologies," December 2004

sufficiently polar in structure so that the microwave energy can be absorbed at the appropriate rate to make devulcanization viable. The only reasonable use for microwave devulcanization is on compounds containing primarily a polar rubber, which limits its application. For example, Global Resource Coorporation of the USA has developed a technology whereby petroleum-based materials e.g. waste pneumatic tyres, are subject to microwaved radiation at specifically selected frequences for a time sufficient to partially decompose the materials into a combination of oils and consumable gas.[20]

In the biological process, a bacterial devulcanization is carried out by mixing finely grinded rubber with media containing the appropriate bacteria in a temperature-controlled bioreactor. The slurry is then maintained at a prescribed temperature and pressure for the duration of the treatment. Biological contact time is approximately ten to a few hundred days. Next, the processed material is filtered to remove microorganisms, dried and sold.

Information available on the environmental impact of devulcanization is limited to the chemical and ultrasonic processes. In both cases, emissions of atmospheric pollutants and liquid effluents do occur.

A report published by Calrecovery Inc. (2004) lists emissions of approximately 50 organic compounds, including benzene, toluene, and heptanes. There is also a possibility that hydrogen sulphide (H2S) and sulfur dioxide (SO2) will be released through the oxidation of hydrogen sulphide (H2S). As a result, the process will require filters to control emissions and gas scrubbers to remove sulfur dioxide (SO2). Regarding liquid effluents coming from the scrubber, they should be dealt with appropriately before they are launched into water bodies.

Table 13 includes information about the costs and production capacities of devulcanized rubber.

**Table 13 – Estimated Costs for Producing Devulcanized Rubber**

| Item | Chemical Process | Ultrasonic Process |
|---|---|---|
| Capacity ( kg/h ) | 34 | 34 |
| Capital cost (US$ $10^3$) | 166 | 163 |
| O&M costs (US$ $10^3$) | 172 | 136 |

*Source: Calrecovery Inc. "California Integrated Waste Management Board" – 2004*

### (c) Pyrolysis

Pyrolysis is the thermal degradation process carried out in the absence of oxygen or under conditions in which the concentration of oxygen is sufficiently low not to cause combustion.

This process usually produces oil with low energy content (when compared to diesel oil), a synthetic gas, known as syngas (with low heat properties), carbon black char and steel. The process is complex and is considered to have limited application for waste tyres.

Pyrolysis char produced in this process has low commercial value, as it consists of a mixture of the different types of carbon blacks used in the manufacture of tyres. Therefore, the resulting product does not have the same quality as those of the original carbon blacks used in the manufacturing of tyres.

In order to improve its characteristics, for the purpose of using it to develop new products, particle size reduction may be carried out to upgrade the pyrolysis char. Resonance disintegration produces ultrafine carbon products from pyrolysis char. During resonance

[20] Gert-Jan van der Have, Recycling International, April 2008, p. 40-43

disintegration, char granules experience multiple high-energy shock waves, resulting in the immediate production of carbon having an average primary particle diameter of 38 nanometers in aggregates and agglomerates ranging in size from 100 nanometers to 10 microns.[21]

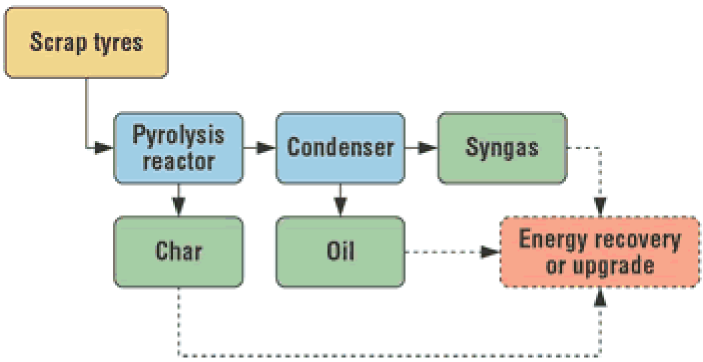
Another possibility is to use pyrolysis char as activated carbon. But, upgrading techniques are not considered to be economically viable in view of the current limited market demand for the product.

There have also been difficulties in obtaining markets for waste steel recovered from pyrolysis. This material is often contaminated with carbon, making it undesirable to many metal re-processors. Usually, the recovered steel is also in the form of a tangled, high volume mass, which makes it difficult and costly to handle and transport.

In U.S, pyrolysis does not yet proven to be an economically viable operation. Pyrolysis has been attempted over 30 times and has always failed as a full scale operation and investors have lost millions and the states have had to incur costly cleanup. The process of Pyrolysis has the capability of creating hazardous waste pyrolytic oils and they need ot be managed accordingly.

For all of these reasons, it was expected that pyrolysis will only play a limited role in waste tyre management.[22] The pyrolysis process flow is show in Figure 6.

**Figure 6 – Pyrolysis of Scrap tyres**




*Source: Juniper consulting, WMW Technologies and Treatment, 2004*

### (d) Civil Engineering

Civil engineering applications of waste tyres are addressed in standard ASTM 6270/1998B and also in works by Hylands and Shulman.[23] Table 14 shows examples of these applications.

**Table 14 – Examples of Civil Engineering Application for Waste Tyres**

| Application | Material | | | | | | | | | | | Source | Technology |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | W | X | S | C | G | P | B | R | D | Y | Z | | |
| Artificial reefs | x | | | | | | | | | | | PW | M |
| Concrete construction additives | | | | | | | | | | x | | ALL | P |
| Embankments | x | | x | x | | | | | | | | PW, TW, MT | M, A |

21 Karpetsky, Timothy. “Resonance disintegration produces ultrafine carbon products from pyrolysis char for use in printing inks,” *Paint India* vol. 51, nº12, pp. 73-80, 2001,
22 WMW Technologies and Treatment, 2004.
23 Hylands, K.N. Shulman, V. ´Civil Engineering Applications of Tyres.” Reporting VR 5. Viridis. 2003.

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Erosion Control | x | x | x | x | | | | | | | | PW, TW | M, A |
| Landfill engineering | x | | x | x | | | | | | | | PW, TW | M, A |
| Slope stabilization | x | | x | x | | | | | | | | PW, TW | M, A |
| Temporary roads | x | x | x | x | | | | | | | | PW,TW | M, A |
| Thermal insulation | x | | x | x | | | | | | | | PW, TW, MT | M, A |
| Collision barriers | x | x | x | x | | | | | | | | ALL | M, A |
| Light weight fill | x | | x | x | | | | | | | | PW, TW, MT | A |
| Noise barriers | x | x | x | x | | | | | | | | PW, TW, MT | M, A |
| Asphalt additives | | | | | | x | | | x | x | | ALL | P, D |
| Asphalt rubber | | | | | x | x | | | | | | PW, MT | A, C |
| Road furniture | | | | | x | x | | x | x | | | ALL | A, C, R, D |
| Train and tram rail beds | | | | x | | | | | | | | PW, TW | M, A, C |

*Source: Adapted from Hylands and Shulman 2003*

**Key to Table 14**

| *Materials* | | *Source* | | *Technology (size reduction)* | |
|---|---|---|---|---|---|
| W | Whole tyres | PW | Whole passenger car tyres | M | Mechanical (cut, compress) |
| X | Cut tyres | TW | Whole truck tyres | C | Cryogenic size reduction |
| S | Shred | MT | Mixed whole car/truck tyres | A | Ambient size reduction |
| C | Chips | TT | Truck tyre tread | B | Buffing |
| G | Granulate | PT | Car tyre tread | D | Devulcanization |
| P | Powder | OT | Other tyre (agricultural, bicycle) | R | Reclaim |
| B | Buffings | ALL | All tyres | P | Pyrolysis |
| R | Reclaim | O | Other technologies | | |
| D | Devulcanizates | | | | |
| Y | Pyrolytic products | | | | |
| Z | Upgraded materials | | | | |

Table 15 shows estimates of the quantity of tyres necessary for some of the applications mentioned in Table 14.

**Table 15 – Estimates about the Quantity of tyres Necessary for Specific Applications***

| ***Application*** | ***Quantity truck/car*** | ***Unit of application*** | ***Form*** |
|---|---|---|---|
| Sea embankment | 3,000 car tyres | 500m x 1.5m high | Whole |
| Temporary road | 3,000 truck tyres | 1km of road | Whole |
| Artificial reef | 3,000 truck/ 30,000 car tyres | 1km x 1m high | Whole/bale |
| Breakwater | 4,000 tyres | 1km x 0.7m high | Whole/bale |
| Construction anchor | 4 truck tyres | 40 tyres per anchor | Whole/bale |
| Retaining wall | 5,000 tyres | 500m x 2m high | Whole/cut |
| Slope stabilization | 750 tyres | 500m x 1m high | Whole/cut |
| Sound barrier | 20,000 tyres | 1kmx3m high | Whole/cut |
| Embankment | 2,100 car tyres | 500m x 1.5m high | Whole/cut/bale |
| Heavy load road | 200,000 car tyres | 350m x 10m wide | Whole/cut/bale |
| Drainage culvert bed | 1200 tyres | 1km | Whole/cut/bale/shred |
| Backfill | 80-100 car tyres | 1 cubic meter | Shred |

| | | | |
|---|---|---|---|
| Bridge abutment fill | 100,000 tyres | 1m wide x 200mm | Shred (compacted) |
| Sound barriers | 20,000 tyres | 1 km x 3m high | Shred |

* The technologies here presented are not recommendations for the ESM of tyres. For sure, the number of tyres used will depend on the specifications of the project.
*Source: Hylands and Shulman 2003*

### i. Landfill Engineering

Applications for waste tyres in landfill engineering include:

(ii) Leachate collection;
(iii) Protective layer for the geotextile;
(iv) Drainage layer in landfill cover;
(v) Fill for landfill gas drainage systems;
(vi) Daily cover for landfills;
(vii) Temporary roads;
(viii) Tyre bales in landfill haul roads.

These applications use whole tyres, cut tyres (up to 300mm), tyre shreds (50mm to 300mm), and tyre chips (10mm to 50mm). The choice of tyre grading will depend upon the costs for rubber processing and transportation, their availability, as well as environmental requirements at the facility site. It also depends on the type of landfill project and its legal requirements.

### ii. Light Weight Fill and Soil Enforcement

Tyres are used as lightweight fill in a wide variety of engineering projects, such as lightweight fill for use behind retaining structures and in embankments, backfill to integral bridge abutments and slope repair and stabilization, and slope stabilization, partially replacing quarried aggregate, gravel and aggregate filled gabions, depended of the project.

These applications use whole tyres, cut tyres (up to 300mm), tyre shreds (50mm to 300mm), and tyre chips (10mm to 50mm).

### iii. Erosion Control

The durability and stability of tyres provides them with ideal properties for use in works project for erosion control. tyres have been used both for coastal and fluvial erosion control projects, for the purpose of absorbing the energy created by moving water, either tidal or fluvial flows, as well as that derived from rainwater.

Waste tyres have also been used in the environmental reclamation of eroded gullies and small canyons through filling, as well as in the construction of erosion control barriers, thus becoming part of the eroded landscape, which will be later replanted with vegetation.

### iv. Noise Barriers

Noise barriers built with tyres are used to alleviate noise levels at highways. Noise barriers are built using whole tyres, shredded tyres or mats and special mats made of rubber granulate. Several types of barriers are currently being developed for this purpose.

### v. Thermal Insulation

Tie cuts, shreds and chips are used a thermal insulation material. The thermal resistivity of tyres is around seven or eight times as high as that of gravel. In countries with a temperate climate and very low temperatures, they can be used to insulate road and street structures, including below asphalt to reduce cracking from frost, and as fill in pipeline construction, especially for water pipe. Highway edge drains built with tyres have been shown to resist freezing during very cold winters.

### vi. Applications in Rubber-modified Concrete

Rubber-modified concrete improves the absorption of impact energy and the occurrence of cracks. Work in Brazil has concentrated on the use of rubber-modified concrete in the construction of highway barriers and other products with a mixture of conventional concrete, rubber aggregate and fiber glass.

### vii. Road Applications

Granulated materials obtained from waste tyres have been used in the development of rubber-modified asphalt in the United States, Western Europe and Brazil. There are two main processes for producing rubber asphalt (Caltrans,[24] Hylands and Shulman), i.e. the wet process and the dry process.

In the dry process, crumbed rubber is added directly into the asphalt and there is some reaction between the rubber and the bitumen. This process, however, is limited to the application for hot mix paving projects, and is not a suitable method for surface treatments.

In the wet process, crumbed rubber is used as a bitumen modifier. Crumbed rubber is blended with bitumen before the binder is added to the aggregate. The ideal particle size for the wet process ranges from 0.6 and 0.15 mm. Material should be heated to between 149-190°C before compaction. This makes the process more expensive than conventional asphalt and there is the probability of emissions of toxic substances, both during production and application. The wet process, however, has demonstrated to have better physical properties.

Rubber asphalt is still not widely accepted, and its environmental impacts have not been fully analyzed. It also requires higher initial investments. In Europe, only one percent of rubber granulates is used for highway surfacing. This contributes to the disposal of just a little over one fourth of one percent of the waste tyres Europe generates. The U.S. Congress began to require the use of rubber asphalt for federally funded projects in 1991, but environmental and public health concerns lead to its withdrawal five years later.[25] While several states in the U.S. use rubber asphalt in their highway projects, research related to its impacts on the environment and health of workers is ongoing.[26] Today, rubber asphalt applications account for the disposal of two percent of tyre wastes.[27]

A study commissioned by the Australian government summarizes the situation as follows: The improved performance comes at a higher cost not only due to the higher cost of the rubber granulate, but also due to the increase in processing time and new techniques, less adequate for the equipment used in the construction and repair of highways, and is not within the level of expectation of the operators. There is also concern with regard to emission of air pollutants, when the road surface is reconditioned.

Similarly, a study carried out by the environmental agency of the United Kingdom, where the use of rubber asphalt has been limited notes that: Highways using rubber granulates last twice as much as conventional highways, but cost almost twice as much to produce. There are also reports that these surfaces have the potential to catch fire under certain

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[24] Caltrans. Asphalt Rubber Usage Guide. “Materials Engineering and Testing Services-MS #5.” Office of Flexible Pavement Materials. January 2003.

[25] Intermodal Surface Transportation Efficiency Act of 1991, § 1038(d), Pub. L. 102-240, 105 Stat. 1914 (1991); NHS Designation Act of 1995, § 205(b), Pub. L. 104-59, 109 Stat. 588 (1995)

[26] US Department of Transportation, Federal Highway Administration, Crumb Rubber Modifier.

[27] John Sheerin, Chair of Scrap tyre Committee of Rubber Manufacturers Association, “Markets & Trends in the US Scrap tyre Industry,” presentation at a meeting of the Canadian Rubber Association, 20 October 2004, at slides 13, 23

conditions, for example the high temperatures found in some parts of the U.S. In addition the surface can be slippery, and there is the possibility of the generation of hazardous vapors when the surface is being removed.

In the U.S, the National Institute for Occupational Safety and Health (or NIOSH) report cited concludes that rubberized asphalt does not contribute fumes that exceed exposure limits established by safety and health regulatory agencies.[28] The composition of the emissions and fume may vary, but it is sourced from the base asphalt, not from the rubber. In all cases, emissions and fume are within the limits of every US permitting and regulatory authority.

The use of rubber in asphalt is highly regional based costly upon the standards developed by each individual state in the USA. Some states have not yet developed standards for the use of tire rubber in asphalt. In states where rubberized asphalt is routinely used, the percent of tire being used in the application ranges from 10-85%. The use of waste tires in road paving applications is a cost effective beneficial use for an end of life tire and an extremely viable market. Tire rubber is an excellent additive to asphalt material to reduce the age hardening of asphalt material and to reduce cracking to prolong pavement service life.

**(e) Industrial and Consumer Products**

These applications involve lamination, which consists of several cutting operations carried out on waste tyres to extract sections and portions with a specific shape. Since only certain parts of the tyre are used in these applications, left over residues, such as steel cord, beads and treads will still be required to be adequately disposed of.

Other applications to produce industrial and consumer products are addressed in works by Hylands and Shulman (see footnote 34) and by the Questor Centre.[29] They include the following:

(i) Sports surfaces

(ii) Indoor safety flooring

(iii) Playground surfaces

(iv) Shipping container liners

(v) Conveyer belts

(vi) Automobile mats

(vii) Footwear

(viii) Carpet underlay

(ix) Roof tiles

(x) Flooring

(xi) Activated carbon (Carbon black)

(xii) Livestock mattresses

(xiii) Thermoplastic elastomers

**(f) Co-processing**

Studies on the use of tyres in cement kilns do not present consistent results about the impacts of co-incineration on the detectable levels of dangerous substances. Thus, the

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[28] National Institute for Occupational Safety and Health (NIOSH), Department of Health and Human Services, “Crumb-Rubber Modified Asphalt Paving: Occupational Exposures and Acute Health Effects” vi (2001)

[29] Questor Centre – “New Products Incorporating Tyre Materials,” Investment Belfast, 2005

convenience of authorizing the co-incineration of tyres in cement kilns needs to be considered on a case by case basis as its safety is dependent on good operating practice as well as the particular characteristics of the tyres used and the kiln.

### i. Co-processing in the Cement Industry

Co-processing refers to the use of waste materials in industrial processes in cement production. It is a way to recover energy and material from refuse, when used to partially replace fuel and raw material in the production of cement.

Burning temperature in cement kilts is about 1450º C with the flame temperature up to 2,000ºC. Therefore, the high heat value (32.6 MJ/kg) of tyres as compared to coal (18/6 to 27.9 MJ/kg) is quite attractive. However, depending on market circumstances, costs of using tyres as fuel can be higher than those for fossil fuels. In addition, there are costs related to shredding in those kilns unable to burn whole tyres, and costs arising from the implementation of specific emissions' controls for the pollutants released in tyres' incineration.

According to Menezes[30], the use of waste tyres as an alternative fuel source (tyre derived fuel - TDF) has generated controversies, particularly in the United States and in European countries. One of the reasons has to do with the high level of investments necessary for equipment to treat and constantly monitor atmospheric emissions.

In the U.S.A, currently more than 80 facilities in about 30 states incinerate waste tire material for energy recovery. A total of 130 million waste tyres were used as tire-derived fuel (TDF) in 2003, up from 25 million in 1990.[31]

Annex C, part II of the Stockholm Convention, lists cement kilns co-processing hazardous wastes as an industrial source with potential for the formation and liberation of comparatively high amounts of polychlorinated dibenzo-p-dioxins (PCDD), dibenzofurans (PCDF), hexachlorobenzene (HCB) and polychlorinated biphenyls (PCB) into the environment. The revised draft guidelines on best available techniques (BAT) and provisional guidance on best environmental practices (BEP) relevant to Article 5 and Annex C of the Stockholm Convention on persistent organic pollutants, adopted at the Conference of the Parties to the Stockholm Convention in April-May 2007, adress this issue and present valuable information. The BAT/BET guidelines state the following:

> "The combustion process in the kiln, has the potential to result in the formation and subsequent release of chemicals listed in Annex C of the Stockholm Convention. In addition, releases from storage sites may occur. Well-designed process conditions, and the installation of appropriate primary measures, should enable cement kilns firing hazardous waste to be operated in such a manner that the formation and release of chemicals listed in Annex C can be minimized sufficiently to achieve concentrations of PCDD and PCDF in flue gases of < 0.1 ng I-TEQ/Nm3 (oxygen content 10%), depending on such factors as the use of clean fuels, waste feeding, temperature and dust removal. Where necessary, additional secondary measures to reduce such emissions should be applied."

Data on the emission during co-processing of tyres in cement kilns are controversial. Proponents of TDF argue that, with correct techniques and equipment, the combustion of tyres and other wastes is no different than coal combustion. However, the data available do not always support this argument. Researchers at the Okopol Institut fur Okologie

30 Menezes – Evaluation of the Emissions from the Thermal Degradation of Tires. 2006 – Rio de Janeiro
31 U.S Environmental Protection Agency

und Politik, in Germany, concluded that "incineration of tyres significantly raises inputs of zinc and lead into a cement kiln and also causes between a two-fold and a five-fold increase of dioxin emissions."[32]

In a study conducted for the state of California, Professor Seymour Schwartz of the University of California examined four cement kilns while burning up to 20% of tyres and reported the following results:

(i) Dioxins and furans increased between 53% and 100% in 4 of 4 tests;
(ii) PAHs increased between 296% and 2230% in 3 of 4 tests;
(iii) Lead increased between 59% and 475% in 3 of 4 tests;
(iv) Chromium increased 727% in one test, with much smaller decreases in others;
(v) Only the emissions of nitrogen and the sulphur oxides showed better results[33.]

While Professor Schwartz does not oppose TDF in this report, he subsequently explained the following:

> "The risk assessment could be estimating only a small fraction of the total risk because of lack of knowledge of the causal mechanisms of the health effects. Virtually nothing is known about the dose-response functions for important categories of health effects, particularly disruptions to the hormone systems of humans, which could produce life long damage in developing infants. Also, virtually nothing is known about the health effects caused by combinations of toxic chemicals that are emitted when burning tyres. Without such scientific knowledge, and because some toxic pollutants increase from burning tyres, there is no scientific basis for the Board to conclude that burning waste tyres in cement kilns is safe".[34]

A study by the U.S. Environmental Protection Agency (EPA) concluded that a TDF can be used successfully as a 10 - 20% supplementary fuel in properly designed solid-fuel combustors with good combustion control and add-on particulate controls, such as electrostatic precipitators or fabric filters. Furthermore, a dedicated tire-to-energy facility specifically designed to burn TDF as its only fuel has been demonstrated to achieve emission rates much lower than most solid fuel combustors" (Air scrap emission, 1997).

In the United Kingdom, community groups and environmentalists have criticized the Environmental Agency's (EA's) endorsement of TDF and other alternative fuels.[35] The report from the House of Commons Environmental Committee expresses concerns citing their own evidence "which revealed a number of deficiencies in the EA's handling and interpretation of environmental monitoring data."[36] The committee has established that "the EA

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32 Joachim Lohse & Jan Wulf-Schnabel, Okopol Institut fur Okologie und Politik GmbH, *Expertise on the Environmental Risk Associated with the Co-Incineration of Wastes in the Cement Kiln "Four E" of CBR Usine de Lixhe, Belgium (*High ex positions to zinc and its compounds can create a wide range of health problems, from chest pains to coughs and reduction of pulmonary capacity. See Agency for Toxic Substances and Disease Registry, Department of Health and Human Services (US), Toxicological Profile for Zinc (1995).

33 Seymour Schwartz et al., "Domestic Markets for California's Used and Waste tyres, Attachment A: Environmental and Health Consequences from Using tyres as Fuel;" Health Risk Assessment 1 (1998).

34 Letter from Seymour I. Schwartz, Professor of Environmental Science and Policy at University of California-Davis, to California Integrated Waste Management Board, 21 January 1998)

35 *Plumes ground in Rugby?*, Air Quality Management, April 2004; Mines and Communities Project

36 Memorandum from The Air That We Breathe Group to Select Committee on Environment, Transport and

must act to restore public confidence in its regulation of the cement industry," in part, through unannounced inspections, in which "inspectors should not automatically believe what they are told by the industry."[37] This could explain why "the speed of regulatory approval for cement works to consume used tyres as a replacement fuel has to date been extremely slow," as noted by the U.K. Working Group on Used Tyres.[38]

The University of Karlsruhe[39] (Achternbosch at al, 2005) also conducted a study of heavy metals in cement resulting from the co-incineration of waste. The study indicates that the release of trace elements from cement is negligibly small during the phase of use.

Yet another study to assess the impact of the use of 40% waste tyres to replace coal on the health of workers was conducted in Rugby,[40] England, in 2002 and the results were the following:

(i) Emissions from the plant depend on the content of the fuel used, the contents of raw materials used in cement production, the details about the plant construction and how it is operated.

(ii) Tyres contain much more zinc than coal and emissions from this will increase, but are not expected to pose any significant health hazard. Emissions of most other trace metals are predicted to be unchanged or to fall.

(iii) Measuring dioxins is difficult and levels currently emitted from the plant are around the detection threshold. Dioxins are biologically active, and are associated with cancer and other adverse effects. Experience at other plants suggests that burning tyres does not produce a measurable change in dioxin emission. Additional impacts from changing fuel are not expected.

(iv) Particulates are products of combustion. Those of health import have a diameter less than 10µm (PM10). Raised ambient PM10 levels have adverse effects on health. The effect of tyre burning on particulate emissions is unclear but there may be a small increase.

(v) High NOx levels are associated with worsening of already existing lung disease. tyre burning will probably reduce NOx emissions which will constitute a positive health impact. (Note: Reducing does mean eliminating. Therefore, there is no positive impact on health, but rather a reduction in the negative impact).

(vi) There is likely to be no change in sulphur dioxide emissions with the change in fuel.

**ii. Experience from Plants that Have Used Tyres as Fuel**

There are several types of kilns that use different technologies, and the

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Regional Affairs, House of Commons, Appendix I, 1999

37 *Ibidem*.

38 Used Tyre Working Group (UK), Sixth Report of the Used Tyre Working Group 18 (2003) ("UTWG Sixth Report") "). *See also* A. B. Hird et al., Tyre Waste and Resource Management: A Mass Balance Approach 3 (2002) ("Mass Balance")

39 Achternbosch at el, "*Heavy Metals in Cement and Concrete resulting from the Co-incineration of Waste in Cement Kilns – Karlsruhe GMBH*", Karlsruhe 2003

40 COOK, Andrew.(2002) "*Health Impact Assessment Report on proposal to substitute chopped tyres for some of the coal as fuel in cement kiln*". Department of Public Health and Epidemiology. University of Birmingham.

experience verified in one kiln is not a reliable indicator of how another kiln will perform. It is recommended that, in addition to emissions already being monitored (NOx, SOx, CO, and particulate matter - PM10), additional information should be obtained more frequently about emissions of dioxins, trace metals and the profile of particulates emissions.

If monitoring indicates that statutory emissions are being exceeded during test burn, the burn should be stopped until the cause of that instability has been established and rectified. Tyre burning should only be allowed on a permanent basis if the data from the test burn shows that co-processing will not lead to additionalrisks to the environment.

A study[41] prepared by the Foundation for Scientific and Industrial Research of Norway (SINTEF 2006), under the sponsorship of the World Business Council for Sustainable Development (WBCSD), analyses POP´s emissions in the cement industry from various wastes used as alternative fuels, and not only waste tyres.

According to this study, PCDD/F formation and subsequent emission requires the simultaneous presence of the following factors of influence:

(i) Particulate surfaces, i.e. sites which can catalyze their formation;

(ii) Hydrocarbons and chloride(s);

(iii) Appropriate temperature window between 200°C and 450°C, with a maximum at around 350°C;

(iv) Appropriate residence time, probably more than 2 seconds.

The work by Menezes, which focused on emissions from the thermal degradation of tyres concludes that a higher number of aromatics and cyclic compounds, such as Benzene and Furans were detected at combustion temperatures between 450º C and 650º C.

Also in this study, the following primary measures are considered to be critical to avoid the formation and emission of PCDD/F from cement kilns:

(i) Quick cooling of kiln exhaust gases to lower than 200°C in long wet and long dry kilns without preheating. In modern preheater and precalciner kilns this feature is already inherent.

(ii) Limit or avoid alternative raw material feed as part of raw-material-mix if it includes organic materials.

(iii) No alternative fuel feed during start-up and shut down.

(iv) Monitoring and stabilization of critical process parameters, i.e. homogenous raw mix and fuel feed, regular dosage and excess oxygen.

The following overall primary measures (with optimization integrated into the process) are important to ensure an emission level of 0.1 ng PCDD/F I-TEQ/Nm3:

(i) Process control optimization, including computer-based automatic control systems;

(ii) The use of modern fuel feed systems;

(iii) Minimizing fuel energy by means of preheating and precalcination, to the extent possible.

(iv) Careful selection and control of substances entering the kiln can

[41] Formation and Release of POP´s in the Cement Industry, World Business Council on Sustainable Development / SINTEF – January 2006.

reduce emissions and when practicable, homogeneous raw materials and fuels with low contents of sulphur, nitrogen, chlorine, metals and VOC should be selected.

Based on the studies above, cement kilns operating within TDF has to deal with additional risks, regarding to the toxic air emission it can generate.

This solution has been the subject of increasingly heated discussions, for two basic reasons:

(i) The use of tyres for energy generation reduces the possibility of their being used as a higher value-added product in other applications. This should be assessed in the context of the waste treatment hierarchy. Obviously, when tyre reuse or material recycling can be practiced, these options are preferable but should always be assessed with a Life Cycle methodology including the alternative waste treatment routes and the substitution of natural resources.

(ii) The concern over potential emissions during the burning process. Operating within appropriate conditions, can reduce but not completely eliminate the risks to health and the environment.

Over the last two years, an increasing active participation of groups that are opposed the licensing of tyre co-processing in cement kilns has resulted in the elimination of TDF as alternative fuel in five plants in the United States, and a halt in the licensing process of four others.[42]

With regard to the EU, the waste incineration directive (2000/76/EC) establishes lower emission limits since 28 December 2005 for all plants covered. Temporary exemptions from the NOx and dust emission limit values for cement kilns co-incinerating waste was given until 1 January 2008. The consequence would be the deactivation of the cement kilns that do not reach the low emission limits. Cement kilns using the wet process would be particularly affected by these more stringent limits.

One factor that is also beginning to weigh against the use of traditional fossil fuels like pet coke as a fuel is related to carbon dioxide (CO2) emissions. Currently, the burning of fossil fuels accounts for about 40% of the emissions from the cement industry. By 2020, projections indicate that demand for cement will rise 180% relative to 1990 levels.

The cement industry, as part of the “Cement Sustainability Initiative”, aims to maintain emissions at 1990 levels despite this increase in demand. This means a reduction of about 40% in CO2 emissions.[43]

In this context, according to the same report, beginning in 2010, alternative fossil fuels (i.e., solvents and tyres) will be increasingly targeted for (CO2) emission reduction. These fuels should therefore be considered to be interim fuels.

### iii. Co-processing in Plants for Electric Power Generation

According to Menezes (see footnote 47), incineration is a thermal oxidation process, at high temperatures, ranging from 800º C to 1300º C, used to eliminate organic wastes, reducing volume and toxicity. Regardless of the objectives for which the burning is conducted, emission control should be strictly enforced, as required by legislation.

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42 US Scrap Tyre Markets 2003 / 2004 edition

43 Climate Change /Final Report 8 / 2002 /Pg 24 - Battelle Institute / World Business Council for Sustainable Development

It is essential that variables, such as combustion temperature, residence time, turbulence (indicating the level of mixture between oxygen and the waste, which should be maximized to increase molecule destruction) oxygen concentration and particle diameter, be strictly controlled in the incineration process.

Plants incinerating elastomers, such as tyres or otherwise, should use state of the art technology to avoid a broad range of emissions due to the wide variety and concentration of additives used in these polymers. Gases derived from the burning of elastomers produce elements with a high level of toxicity, therefore they require treatment. Dioxins, furans, polycyclic aromatic hydrocarbons (PAH´s) are all by products of the combustion process, which require special controls due to the serious injuries to human health and the environment that they can cause. A number of potentially harmful materials can be produced from combustion of many fuels such as coal and oil, as well as tires, so the combustion process must have appropriate combustion conditions and emission controls to meet all applicable regulations.

Thus, incineration is a technology that requires substantial capital investment and faces strong public opposition. Several plants have experienced operational problems, which have hindered the reliable supply of electric power. Combustion is capital intensive. Substitution of TDF for a portion of other solid fuels in existing combustion units generally requires limited investment in appropriate metering equipment to control the rate of TDF addition. There are very few systems dedicated solely to combustion of waste tires, and these are capital intensive for power generation due primarily to comparatively small economics of scale. Some of these plants have encountered economic viability issues as have systems powered by wood and other renewable energy sources.

Various incinerators, including plants such as those of Gummi-Mayer (Germany), Sita-Elm Energy (England) and Modesto tyres (California. U.S.) have all been closed as a result of these problems. Among those that continue to be operational are Exeter (U.S.), Marangoni (Italy), and Ebara (Japan).

### (g) Others

#### Monofill Pratice

The disposal of waste tyres in dedicated landfills is now prohibited in many countries. Monofills are dedicated landfills or general landfills, with a portion that is used for the disposal of a specific product.

Important factors that should be taken into account when managing a monofill are: minimizing environmental risks in routine operations, and minimizing the risk of fires.

There is little technical information available on how to build and operate dedicated lanfills, which clearly reflects the prohibitions against the disposal of tyres in landfills that exist in many countries. Information was found only in two documents, one published by the California Integrated Waste Management Board (CIWMB) and the other published by the Ohio Branch of the Environmental Protection Agency (Ohio EPA), the Ohio Administrative Code (Rules 3745-27-60, 73, 74). These documents provide information about best practices for building a monofill.

Table 16 provides an overview of best practices for managing a monofill.

**Table 16 – Best Practices for Managing Monofill Facilities**

| Criteria | CIWMB | Ohio EPA |
|---|---|---|
| Operating criteria | General landfill procedures | N/R |

| | | |
|---|---|---|
| Monitoring | Temperature sensors within underlying cells if >1 cell thick<br>Monthly collection of waste tyre samples and analyzed for degradation/protruding wire | N/R |
| Records | Monitoring results and tyre handling manifests | Annual operating report |
| Closure and post closure maintenance | General landfill procedure | General landfill procedure |

Sources: California Integrated Waste Management Board (October 2003) *"Waste tyre Monofill Proposed Regulatory Requirements,"* and Ohio Administrative Code, *"Rule 3745-27-60: General Storage and Handling of Scrap tyres", "Rule 3745-27-73: Final Closure of a Scrap tyre Monofill Facility"* and *"Rule 3745-27-74: Post-Closure Care of Scrap tyre Monofill Facilities".*

Disposal in landfills may not be considered an alternative, given that currently the laws of most countries ban this type of disposal. In landfills, tyres use valuable space, are not biodegradable and frequently rise to the surface, creating a new range of landfill management concerns

**Artificial Reefs**

Artificial reefs using waste tyres have been built in Australia, the Philippines, Malaysia, North America and the Caribbean.

However, artificial reefs may pose problems that should be taken into consideration, including:

(i) There are controversies regarding the leaching of petrochemical or heavy metal toxicants from tyres into the marine environment. This issue has not yet been satisfactorily resolved;

(ii) Tyres are inherently unstable in salt water. As a consequence, they must be ballasted in order to ensure that tyre units do not move in response to tidal or current movement;

(iii) Ballasted tyre units are bulky and heavy, they require heavy equipment to be transported and assembled. This operation requires a skilled workforce and specific equipment, which makes the process expensive;

(iv) There is disagreement regarding whether or not fouling, or epiphytic communities attach to tyres; and

(v) Even when ballasted, multiple tyre units that use steel reinforcement rods as a connector will separate after several years due to corrosion of the rods, posing serious maintenance concerns.

## Appendix I – Public health literature

Dengue is transmitted by mosquitoes breed in containers which collect rainwater, particularly used tyres.[44] A single tyre can serve as a breeding site for thousands of mosquitoes in only one summer.[45] The Center for Disease Control and Prevention in the United States recognizes that "infestation may be contained through programs of surveillance, removal of breeding sites (especially tyres), interruption of interstate dispersal of tyres, and judicious use of insecticides in breeding sites." Mosquito eradication programs are costly and only minimize the problem, rather than solving it.

One example of this is the species Aedes albopictus (also known as the Asian "tiger mosquito"). This species was accidentally transported from Japan to the Western Hemisphere in the mid-1980's in shipments of used tyres.[46]

Since then, the species established itself in various states in the U.S. and in other countries in the continent, including: Brazil, Mexico, Argentina, Guatemala, Cuba and the Dominican Republic.[47] Therefore, it seems to be clear that the spread of the Asian "tiger mosquito" benefited from the movement of used tyres among states and countries.

The risks associated with the transportation of used and waste tyres are well known, and specialists and environmental authorities in the United Kingdom, U.S. and Canada have drawn attention to these risks. A public health official in the United Kingdom has characterized the transportation problem as follows:

> "Through the internal movement of these tyres, you can monitor the movement of these mosquitoes through the interstate highway systems, which is pretty cunning really."[48]

A Japanese study in 2002 demonstrated that tyres transported for final disposal operations (in this case, cement kilns) could be infested with mosquitoes:

> "In the northernmost limit of the mosquito, Higashiyama located on the eastern side of Tohoku district, there is a cement plant in which used tyres are used for fuel and raw materials. These tyres, which could be infested with mosquitoes, are frequently transported from large cities nearby. It has been shown that this kind of economic activity has a strong connection to the spread of Ae. albopictus."[49]

A study from the Centers for Disease Control and Prevention in the United States reported the following:

> "Ae. albopictus, a major biting pest throughout much of its range, is a competent laboratory vector of at least 22 arboviruses, including many viruses of public health importance. The postulated relationship between

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[44] See WHO Dengue Fact Sheet

[45] Ohio Department of Natural Resources, Recycling Tyres : Problems with wasting scrap tyres: Disease Center for Disease Control and Prevention, *Aedes albopictus Infestation – United States, Brazil,* Morbidity and Mortality Weekly Report, 8 August 1986

[46] YAMAGUCHI, E. "*Waste Tyre Recycling*", Master of Engineering Project, University of Illinois, Urbana-Champagne , October 2000 ,

[47] BORGES, Sonia Marta dos Anjos Alves, "*Importância Epidemiológica do Aedes albopictus nas Américas*", Master's Thesis, Faculdade de Saúde Publica, São Paulo, 2001.

[48] "*Biting Back*", Environmental Health Practitioner, December 2004, at 368-371 (quoting Jolyon Medlock, Health Protection Agency, UK, when referring to the dissemination of *Aedes albopictus* in the United States).

[49] KOBAYASHI, M. et al., "*Analysis of Northern Distribution of Aedes albopictus (Diptera culidae) in Japan by Geographical Information System*", Journal of Medical Entomology, Volume 39, No. 1, at 9 (2002).

> dispersal and major transportation routes would be expected for a species transported largely by human activities such as the commercial movement of waste tyres for retreading, recycling, or other purposes. Several of the 28 mosquito-infested sites not located on the interstate system were major tyre retreading companies, other businesses that deal with large numbers of used or waste tyres, or illegal tyre dumps."[50]

Serious epidemics, such as dengue, are closely associated with this process of spreading the vectors that disseminate them. The numbers associated with the dengue epidemic are significant, i.e. approximately 50 million people worldwide are infected every year by the disease, with 500,000 hospitalizations and 12,000 deaths.[51] The World Health Organization (WHO) recognized that dengue is "the most important emerging tropical viral disease" and "a major international public health concern."[52] Its symptoms range from high fever, severe headaches and muscular pain to hemorrhage, frequently followed by swelling of the liver and poor circulation.[53] Complications associated with the disease, dengue hemorrhagic fever (DHF), has a death rate of 5% to 15% when left untreated.[54] Hemorrhagic dengue fever is one of the main causes of infant mortality in various Asian countries, where it originated.

The case of Brazil is illustrative in this respect. Dengue, which was once considered to be eradicated, re-emerged during the 1990s and, according to the WHO, has now reached levels of an "explosive epidemic."[55] The current dengue epidemic in Brazil worsened from 1994 through 2002, reaching a peak of 794,000 cases in 2002. Unlike previous localized waves of the disease, the current epidemic spread throughout the country.[56] Cases of hemorrhagic dengue increased 45 times from 2000 through 2002[57] reaching the high mortality rate of 4.3%, almost eight times as high as the rate in South East Asia.[58] Brazil accounted for 70% of reported cases in the Americas from 1998 through 2002.[59] Today three out of the four serotypes of dengue co-circulate in 22 of the 27 states in Brazil[60], a disturbing fact, since the combination of serotypes increases the probability of complications and death. The introduction of a fourth serotype (DEN-4) is imminent, as a result of air and maritime transport between Brazil and other countries. Following an intense awareness campaign in Brazil, 280,511 cases of dengue, with 61 deaths, were reported from January through October 2006.

Even fumigation is not fully efficient in eliminating the eggs and larvae in tyre piles. The suppression of adult mosquitoes requires the use of adulticides, toxic chemicals that are not environmentally benign. In addition, it is usually difficult for them to penetrate the pile

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50 CHESTER, G. Moore & Carl J. Mitchell, "Aedes albopictus in the United States: Ten-Year Presence and Public Health Implications", Emerging Infectious Diseases, Volume 3, No. 1 (1997).

51 TEXEIRA, Maria da Glória. "Dengue and dengue hemorrhagic fever epidemics in Brazil: What research is needed based on trends, surveillance and control experiences," *Cadernos de Saúde Pública*, Rio de Janeiro, 15, Pg 1307 -1315, 2005

52 World Health Organization, "*Guidelines for Treatment of Dengue Haemorrhagic Fever in Small Hospitals*" ix (1999)

53 WHO Dengue Fact Sheet

54 Donald Kennedy & Marjorie Lucks, "*Rubber, Blight, and Mosquitoes: Biogeography Meets the Global Economy"*, Environmental History, Volume 4 at 369 (1999)

55 See World Health Organization, "Dengue and Dengue Hemorrhagic Fever (2002)" ("WHO Dengue Fact Sheet")

56 See SIQUEIRA, João Bosco et al., "*Dengue and Dengue Hemorrhagic Fever, Brazil, 1981-2002*", Emerging Infectious Diseases, Center for Disease Control and Prevention (US), Volume 11, No. 1 (2005)

57 *Ibidem*.

58 See FIGUEIREDO, Luiz Tadeu Moraes, "*Dengue in Brazil: Past, Present and Future Perspective*", Dengue Bulletin, World Health Organization, Volume 27, p. 25, at 29 (2003); World Health Organization, Case Fatality Rate (%) of DF/DHF in the South-East Asia Region (1985–2004) (2004)

59 See Siqueira, above.

60 *Ibidem*

sufficiently to reach the mosquitoes.[61] When fumigating tyre piles, the mosquitoes tend to concentrate at the bottom of the pile, where fumigation does not reach them in high enough concentrations. Therefore, it is not uncommon for them to become resistant to insecticides. According to Solari (2002),[62] the use of fumigation is costly and ineffective in combating dengue. “Fumigation is associated with government responsiveness, even though it only kills adult mosquitoes and within a week the larvae have matured and we are back to square one.”

Therefore, the disposal of used tyres constitutes a risk factor for the spread of mosquito vectors, in addition to harboring rodents, and is considered a problem from a public health perspective, especially in tropical countries.

The risks involved in the transport of tyres have led to the banning of used tyre imports in many states in the United States.

In addition to the propagation of mosquitoes and rodents, another risk to public health is the burning of tyres, which generate emissions of chemical compounds that are detrimental to human health, such as carbon monoxide, sulfur oxides, nitrogen oxides, polynuclear aromatic hydrocarbons (PAHs), and POPS (persistent organic pollutants), i.e. Policloro dibenzo-p-dioxins and policloro dibenzofurans (PCDD/PCDF), hexaclorobenzene (HCB) and Policlorbifenils (PCB), among others. The reduction or elimination of non-intentional emissions of such substances is regulated by Article 5 and Annex C of the Stockholm Convention.

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[61] University of Rhode Island, Office of Mosquito Abatement Coordination, Mosquitoes, Disease and Scrap tyres

[62] Solari, Alfredo. BID América.

# Appendix II – Leachate literature

## Part A: Summary of reviewed field trials on tyre leachate

| Paper | Date | Place | Method | Leachate Characteristics |
|---|---|---|---|---|
| Humphrey | 1997 | US | Tyre chips above GWT in Maine, GW or leachate collected for 2.5 years, control well. | Substances < PDWS. Substances < SDWS except Fe and Mn. Organics not detected. |
| Horner | 1996 | UK | Soil samples taken from 10-year-old tyre dump in West London. | Elevated soil Cd, Pb and Zn at base of dump, levels decreased exponentially with distance. |
| O'Shaughnessy | 2000 | CA | Tyre reinforced earthfill, leachate collected for two years, no control well. | Field monitoring of the prototype test embankment constructed with tyres above the water table indicates that insignificant adverse effects on groundwater quality had occurred over a period of 2 years[63]. |
| Humphrey | 2001 | US | Tyre shreds below GWT in Maine, leachate and downstream GW collected for 2.5 years, control well. | Highest level of contamination seen at site, with contamination decreasing to near background 3 m downstream. Substances < PDWS at site. Substances < SDWS at site except Fe, Mn, Zn and some organics. |
| Humphrey | 2000 | US | Tyre chips above GWT in Maine, leachate collected for five years, control well. | Substances with PDWS not altered. Al, Zn, Cl and $SO_4$ not increased at site. Fe and Mn increased at site. Negligible level of organics at site. |
| Riaz[64] | 2001 | CA | Shredded tyres in baselayer of road in Manitoba, GW collected, no control well. | Substances < PDWS below site. Substances < SDWS below site except Al, Fe and Mn. Organics not detected. |

*Reference: End of life tyre Management – MWH, New Zealand, 2004*

Notes:

1. Abbreviations used in table for place names: CA, Canada; UK, United Kingdom; US, United States of America.
2. General abbreviations used in table: PDWS, United States primary (health) drinking water standard; SDWS, United States secondary (aesthetic) drinking water standards; GWT, groundwater table; GW, groundwater.

As presented in Section I/D/2., the several factors that may affect the rate of leaching and/or the concentration of tyre leachate compounds in soil, surface water and groundwater are presented below[65]:

(a) **tyre size:** leaching from whole tyres is likely to be slower than leaching from tyre chips or shreds. This is because of the differences in the surface area to volume ratio;

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63 O'Shaughnessy VO, Garga VK. (2000) tyre-Reinforced Earthfill. Part 3: Environmental Assessment. Canadian Geotechnical Journal 37: 117-131.

64 Riaz AK, Ahmed S. (2001) "*Recycling of Shredded Rubber Tires as Road Base in Manitoba: A Case Study*". 2001 An Earth Odyssey. University of Manitoba, Canada

65 See "MWH. July 2004." *Ibid.*

(b) **amount of exposed steel:** if steel is exposed (in the case of tyre chips and shreds), there is a likelihood that the leaching of manganese and iron will be faster than that from whole tyres in which the steel is not exposed;

(c) **chemical environment:** leaching of metals is likely to be more rapid under acidic conditions, while leaching of organic compounds is likely to be more rapid under basic conditions;

(d) **permeability of soil:** leaching is likely to be faster when soils are permeable;

(e) **distance from groundwater table:** the greater the vertical distance from the groundwater table, the less likely the contamination of groundwater;

(f) **distance from tyre storage site:** the further the downstream distance from the tyre storage site, the lower the contaminant concentration in the soil and groundwater;

(g) **contact time with water:** the longer the tyres are in contact with water, the greater the risk of groundwater contamination;

(h) **vertical water flow through soil:** the greater the water flow through the soil (e.g., from rainfall), the greater the dilution of contaminants;

(i) **horizontal groundwater flow:** the greater the groundwater flow, the greater the spread of the contaminant plume; and

(j) **leached compounds at site:** levels of manganese and iron are higher in groundwater when steel is exposed. Levels of aluminum, zinc and organic compounds may be high in groundwater, and levels of zinc, cadmium and lead may be high in soil.

A study of Sheehan, P.J. et all (2006)[66] has performed toxicity testing, toxicity identification evaluation (TIE), and groundwater modeling were used to determine the circumstances under which tire shreds could be used as roadbed fill with negligible risk to aquatic organisms in adjacent water bodies. Elevated levels of iron, manganese, and several other chemicals were found in tire shred leachates. However, the results were different for the leachates collected from tire shreds installed above the water table and below of it. It concludes that, for settings with lower dissolved oxygen concentrations or lower pH, results of groundwater modeling indicate that a greater buffer distance (;11 m) is needed to dilute the leachate to nontoxic levels under various soil and groundwater conditions solely through advection and dispersion processes.

The following studies on use of tyre granulate in artificial sport fields reviewed the impacts of leachate from these granulates on the environment:

**Table 17 – Studies on use of tyre granulate in artificial sport fields**

| Author | Conclusion |
|---|---|
| ALIAPUR et al. (2007)[67] | • Physicochemical results of the percolates show for potentially polluting substances a kinetic independent from the type of granulates used both in-situ and in-lab tests. Analytically detectable trace substances/compounds are dissolved from the surface and from the polymer matrix of the granules in a concentration which falls over time;<br>• According to current research, after a year's experimentation, the results on the 42 |

[66] Sheehan, P.J. et all (2006) - "*Evaluating The Risk To Aquatic Ecosystems Posed By Leachate From Tire Shred Fill In Roads Using Toxicity Tests, Toxicity Identification Evaluations, And Groundwater Modeling*".
[67] ALIAPUR et al. (2007) - "*Environmental and health assessment of the use of elastomer granulates (virgin and from used tyres) as filling in third-generation artificial turf*".

| | |
|---|---|
| | physicochemical parameters identified and on the ecotoxicological tests show that water passing through artificial turf using as filling either virgin elastomers granulated or granulates from used tyres are not likely to affect water resources in the short and medium term. |
| INTRON et al. (2007)[68] | • Leaching of heavy metals and organics chemicals such as Phthalates and Pah's, from recycled car tyres as infill in artificial turf systems stays well within the Dutch limit values for soil and surface water quality. Leaching of zinc is an exception but is not expected to exceed limits values within 10 years. |
| Müller, E. (2007)[69] | • Dissolved Organic Carbon and the organic nitrogen decrease very rapidly initially, subsequently slowing down to a minimum in a time-dependent, substance-specific manner both in the lysimeter trials and the eluate tests. Towards the end of the trial period, after a year, values have already fallen below the limit of determination for most of the individual substances;<br>• The very low PAH concentrations from the granules were found at an identical level in the blank sample (gravel layer without surface); they correspond to ambient (ubiquitous) contamination levels. |

[68] INTRON et al. (2007) - "*Environmental and Health Risks of Rubber Infill: rubber crumb from car tyres as infill on artificial turf.*"

[69] Müller, E. (2007)- "*Investigations into the behaviour of synthetic surfaces exposed to natural weather conditions*"

# Part B: Leachability determinants for use of materials intended for engineering purposes (applicable in the United Kingdom)

| **Application** | **Chemical property** | **Limiting values** (µg / l, unless stated)* |
|---|---|---|
| - Landfill engineering<br>- Lightweight fill and soil<br>- Reinforcement<br>- Bridge abutments<br>- Drainage applications<br>- In ground barriers<br>- Noise barriers<br>- Thermal insulation<br>- Tyre products and surfacings | pH | 5,5 - 9,5 |
| | Conductivity | 1000 µs/cm |
| | COD | 30 mg/l |
| | Ammonia | 0,5 mg/l |
| | Arsenic | 10 |
| | Cadmium | 1 |
| | Chromium (total) | 50 |
| | Lead(total) | 50 |
| | Mercury | 1 |
| | Selenium | 10 |
| | Boron | 2000 |
| | Copper | 20 |
| | Níckel | 50 |
| | Zinc | 500 |
| | Cyanide (free) | 50 |
| | Sulphate ($SO_4$) | 150 mg/l |
| | Sulfide | 150 |
| | Sulfure (free) | 150 |
| | Phenol | 0,5 |
| | Iron | 100 |
| | Chloride | 200 mg/l |
| | PAH | 0,2 |
| - Erosion control (fluvial & maritime)<br>- Artificial reefs | As above (if necessary) | As above (if necessary) |

*[Limiting values relate to the acceptable concentrations of materials into unlined landfill sites based upon the UK Environmental Agency's own internal guidance.
(Environmental Agency – www.environement-agency.gov.uk)

**Notes:**

Limiting values for chemical properties of materials used in engineering applications are dependant upon site specific factors and the type of containment system used on site.

A risk based approach will be adopted by the regulators. In general, the concentrations of contaminants should fall within the requirements of local regulatory guidance. The limiting values provided are based upon those produced by the Environment Agency to determine acceptability of contaminated materials into unlined landfill sites.

It is the leachable concentrations which will play a part in determining whether tyres prove suitable for use in future engineering applications. In addition, where chemical analysis of a material falls below these thresholds, it can be reasonably be assumed that the material will be suitable for the intended use and provide no risks to human health or the environment. However this must be agreed with the regulator before any work takes place, and is subject to the current waste management licensing scheme.

Pollution of controlled waters falls under the control of the UK environmental regulators. However, further licensing may be required from DEFRA for the placement of waste materials in the sea. The regulators may require that leachability testing of the compounds listed above be carried out on any material proposed for use in aqueous applications primarily as a safeguard that the material do not cause harm to groundwater, surface water or marine waters. Concerns apply to potential to impact drinking water supplies.

# Appendix III – Tyre fires documented in the literature

| Location | Year | Duration | Approx. no. of tyres | Incident management | Adverse Environmental effects | Cause |
|---|---|---|---|---|---|---|
| Rochdale, England | 1972<br>April 1975<br>July 1975 | 1 day<br>30 days<br>10 days | 9,000 | None reported | Water supply reservoir still closed | Arson suspected |
| Rhinehart Winchester, Virginia, USA | 1983 | Blazed for 9 months, smoldered for 18 months | 6-9 million | None reported | 800,000 gallons of pyrolytic oil reclaimed. Soil contamination to reported depth of 100ft. Smoke plume rose to 3000 ft and fallout reported in 3 states | Arson suspected |
| Selby, England | 1987 | 80 days | >1,000 | None reported | 21 gallons of oily leachate removed from site-drinking water in-take closed for 2 days as precaution. | Arson suspected |
| Powys, Wales | 1989 | 14 years | 10 million | None reported | Monitoring of zinc, iron and phenol levels in nearby stream. Levels increase with rainfall. Thick black smoke releasing benzene, dioxins and particulates. | Arson suspected |
| Hagersville Ontario, Canada 7 | Feb 90 | 17 days | 12.6 million [70] | 1700 people evacuated [71] Long term monitoring ongoing | 700,000 liters run-off of oil into soil. Creek water contaminated (PAH´s) | Arson suspected |
| Saint Amable, Quebec, Canada 7 | May 90 | 6 days [72] | 3.5 million [73] | 150 people evacuated 12 million Canadian for site decontamination and restoration costs.[74] | Possible contamination of soil and water by oil released from the burning tyres. | Arson a potential cause |
| York, England | 1991 | No data available | > 1,000 | None reported | Low levels of phenols entered into local stream. | No data available |
| Cornwall, England | 1992 | 1 day | No data available | None reported | Phenol and PAH´s detected in runoff water. | Arson suspected |
| Washington, Pennsylvania, USA | Feb 97 | 14 days | 1.7 million | Evacuation of 500 residents and closing of two schools | None reported | Arson suspected |

70 Source (**) Scrap tyre Recycling in Canada : From Scrap to Value/Recyclage des pneus hors d'usage au Canada : La transformation des pneus hors d'usage en produits à valeur ajoutée.

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72 Recyc-Quebec. 2001-2008 Program for the Emptying of Scrap Tire Storage Sites in Québec - Normative Framework.

73 *Ibid*

74 *Ibid*

| | | | | | | |
|---|---|---|---|---|---|---|
| Gila River Reservation, Arizona , USA | Aug 97 | 7 days | 3 million shredded | Monitoring for ground contamination | None reported | Arson suspected |
| Cheshire, England | 1999 | Not clear | 500,000 | None reported | Run off oil contaminating site | Arson suspected |

*Source: Chemical Hazards and Poisons Report From the Chemical Hazards and Poisons Division, December 2003*

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## ANNEX I – RECOVERY AND DISPOSAL OF WASTE PNEUMATIC TYRES: BENEFITS AND DISADVANTAGES

| Application / Product | Benefits | Disadvantages |
|---|---|---|
| Alternative Fuel (Cement kilns or power stations) | ➢ Conserve natural resources;<br>➢ High calorific value;<br>➢ Large volume potential<br>➢ No ultimate waste for cement kilns. | ➢ Mesure equipment required to control emissions<br>➢ Needs generally shredded tyres;<br>➢ Costly to install and operate. |
| Steel electric arc furnace and foundery kilns | ➢ Total and complete recovery of tyre components: carbon, steel, rubber<br>➢ Replace high cost carbon | ➢ Mesure equipment required to control emissions<br>➢ Needs generally shredded tyres<br>➢ Costly to operate. |
| Landfill Engineering | ➢ Lightweight, low density fill material;<br>➢ Good load bearing capacity;<br>➢ Lower cost compared to gravel;<br>➢ Does not need a well qualified labor; | ➢ Potential leaching of metals and hydrocarbonates;<br>➢ The steel cord in the tyre could puncture the lining;<br>➢ Compressibility of the tyre; |
| Light weight or drainage fill | ➢ Reduced unit weight compared to other alternatives;<br>➢ Flexible, with good load bearing capacity;<br>➢ Good drainage; | ➢ Potential leaching of metals and hydrocarbonates;<br>➢ Deformation under vertical load, when a proper soil cover thickness is not used;<br>➢ Difficulty in compaction (need to use more than 10ton roller, six passes, 300mm lift) |
| Erosion control | ➢ Low density which allows free floating structures to act as wave barriers;<br>➢ Tyre bales are lightweight and easy to handle;<br>➢ Durability; | ➢ Tyres should be securely anchored to prevent mobility under flood conditions;<br>➢ Tyres can trap debris, (needs maintenance) ;<br>➢ Anchors can shift over time due to wave action rendering tyre structures insecure;<br>➢ Water action and tyre buoyancy makes the positioning of any permanent protection below the surface very difficult,;<br>➢ Ultimately such tyres to become again waste to eliminate |
| Artificial Reefs | ➢ Resilience; | ➢ Tyres may leach chemical contaminants such as Poly aromatic Hydrocarbons, or Heavy Metals over time, thereby contributing to pollution of the surrounding environment;<br>➢ High remediation costs in the event of project failure;<br>➢ Inherent instability of tyres in sea water;<br>➢ Difficulty in the fixing of epiphytic communities; |
| Thermal Insulation | ➢ Low thermal conductivity;<br>➢ Overall lower cost than traditional materials; | ➢ Compressible;<br>➢ Relatively new product, producers will to need convince the construction industry of it's suitability; |
| Noise Barriers | ➢ Lightweight, and can therefore be used in geologically weak areas where traditional materials would prove too heavy;<br>➢ Free draining and durable; | ➢ Needs monitoring to avoid accumulation of debris;<br>➢ Visual impact; |
| Rubber modified asphalt | ➢ Increased durability<br>➢ Surface resilience<br>➢ Reduced maintenance;<br>➢ Increased resistance to deformation and cracking; | ➢ It is very sensitive to changes in conditions during mixing i.e. requires expert knowledge;<br>➢ Difficult to apply in wet weather;<br>➢ Not applicable when ambient or surface temperatures are less than 13º C; |

| Application / Product | Benefits | Disadvantages |
|---|---|---|
| | ➢ More resistant to cracking at lower temperatures;<br>➢ Aids in the reduction of road noise; | ➢ Possible occupational health problems due to emissions;<br>➢ It cannot be reprocessed like traditional asphalt |
| Rubber modified concrete | ➢ Lower modulus of elasticity which reduces brittle failure;<br>➢ Increased energy absorption making them suitable for use in crash barriers etc;<br>➢ Suitable for low weight bearing structures;<br>➢ Can be reprocessed by grinding and mixing again with cement | ➢ Relatively new product, producers will to need convince the construction industry of it's suitability; |
| Train and tram rail beds. | ➢ Longer life span compared with timber (20 year for rubber beds and 3 –4 for wood or asphalt);<br>➢ Environmentally safe;<br>➢ Better flush with road;<br>➢ Use chips/shreds as vibration damping layer beneath subballas | ➢ More expensive than traditional material;<br>➢ Relatively new product, producers will need to convince industry of its suitability; |
| **Granulate produced with a grinding process to be used in applications such as listed below** | | |
| Outdoor sport surfaces (equestrian, hockey and soccer) | ➢ Skid resistant;<br>➢ High impact resistance<br>➢ Durable;<br>➢ Highly resilient;<br>➢ Easy maintenance; | ➢ Limited market |
| Play ground surfaces | ➢ Smooth with consistent thickness;<br>➢ High impact resistance;<br>➢ Durable;<br>➢ Will not crack easily;<br>➢ Available in various colors; | ➢ Subject to negative opinions as from waste;<br>➢ Limited market. |
| Indoor safety flooring | ➢ Skid resistant;<br>➢ High impact resistance;<br>➢ Durable ;<br>➢ Available in various colors;<br>➢ Easy maintenance; | ➢ More expensive than conventional alternatives;<br>➢ Colors may be limited;<br>➢ Limited market. |
| Shipping container liners | ➢ Possible use with other packaging problems; | ➢ More expensive than conventional alternatives; |
| Conveyer belts | ➢ Possible use as conveyer belt at supermarket stills ; | ➢ More expensive than conventional alternatives;<br>➢ Cannot be used where belt is subject to large stresses, since it may be prone to failure; |
| Footwear | ➢ Water resistant;<br>➢ Long life span;<br>➢ By varying the thickness of the sole the use of the footwear can be changed; | ➢ Could be more expensive to manufacture than conventional product; |
| Carpet underlay | ➢ Easy to use;<br>➢ Recyclable;<br>➢ Conserves natural resources; | ➢ Limited industrial production |
| Roof tiles | ➢ Looks like traditional tile; | ➢ Limited industrial production |

| Application / Product | Benefits | Disadvantages |
|---|---|---|
| | ➢ Durable (40 to 50 years warranty US and Canadian tiles);<br>➢ Lighter;<br>➢ Cheaper long term cost; | |
| Floor tiles | ➢ Resilient;<br>➢ Skid resistant;<br>➢ High impact;<br>➢ Easy maintenance;<br>➢ Recyclable; | ➢ Limited industrial production. |
| Activated carbon (carbon black) | ➢ Preserves virgin material; | ➢ Very expensive process as it needs pyrolysis;<br>➢ Very energy intensive;<br>➢ Low grade activated carbon;<br>➢ Still in the research stage; |
| Live stock mattresses | ➢ Long life span;<br>➢ Easy to disinfect;<br>➢ Reusable;<br>➢ In the long term it is cheaper than alternatives | ➢ Could be more expensive to manufacture than conventional mattresses;<br>➢ Market potential unknown; |
| TPE Thermoplastic Elastomers | ➢ Similar properties to typical elastomeric materials; | ➢ Very limited existing sites |
| Petrosix process - Pyrolysis | ➢ Reutilizes the sub products of pyrolysis (oil and gas); | ➢ Limited capacity because of operational problems caused by tyres;<br>➢ Very limited existing sites;<br>➢ The sludge originating from the process contains metals and other wastes, which for the moment is deposited in abandoned mines, poses an environmental problem; |

*Reference: Adapted from the Questor Centre (2005), Hylands & Shulman (2003) and Aliapur (2004.)*

**Important Observations:**

This list is not exhaustive, but illustrates the most important treatment options and applications in use or under development.

All the applications mentioned above need raw material obtained from end of life tyres either as chips, shreds or granulates. The size reduction and disposal processes used for this purpose, require adequate installations to address environmental and occupational health problems that could otherwise occur. Adequate safety- and control equipement, should be installed when required.

As a general safety recommendation, the use of individual masks, protective headgear, steel reinforced boots, gloves and eye and ear protection should be mandatory to ensure worker health and safety.

The standards mentioned below, contain detailed information on all applications and operational procedures. It is highly recommended that they be consulted to subsidize any decision.

- ASTM International – American Society for Testing Materials:

- "Standard Practice for Use of Scrap tyres in Civil Engineering Applications – Designation D- 6270 – 98" (Reapproved, 2004);

- CEN – Comitê Europeu de Normalização.

- "CWA 14243 – Post Consumer tyre Materials and Applications", June 2002