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Agenda item 3 (b) (i)

Matters related to the implementation of the Convention: scientific and technical matters: technical guidelines

Technical guidelines

Addendum

Revised technical guidelines for the environmentally sound management of used and waste pneumatic tyres

Note by the Secretariat

At its tenth meeting, the Conference of the Parties adopted, as amended, the technical guidelines for the environmentally sound management of used and waste pneumatic tyres on the basis of the draft contained in document UNEP/CHW.10/6/Add.1, which was prepared by a small intersessional working group led by the Government of Brazil. The text of the final version of the revised technical guidelines is contained in the annex to the present note.

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Annex

Revised technical guidelines for the environmentally sound management of used and waste pneumatic tyres

Revised final version (31 October 2011)

Contents

Definitions

Air emission system	Any system designed to capture the physical flow of gaseous or particulate materials from the production or consumption processes, in order to remove pollutants before discharge into the atmosphere.
Ambient size reduction	Mechanical size reduction at or above ordinary room temperature.
Artificial turf	Tyre granulates used as infill in synthetic fields, constituting the primary playing surface.
Backfilling	An operation by which waste is used to refill excavated areas for the purpose of reclaiming slopes, for safety or as filling in landscaping or on landfills.
Bitumen modifiers	Modified bitumens generally use a traditional waterproofing medium – asphalt – modified with atactic polypropylene (APP), styrene butadiene styrene (SBS), synthetic rubber or other agents that create a uniform matrix to enhance the physical properties of the asphalt.
Chips	The result of mechanical processes by which end-of-life tyres are fragmented, ripped or torn into irregularly shaped pieces of typically 10–50 mm in size.
Civil engineering applications	Use of whole, baled, cut, shredded and/or chipped waste tyres for backfilling in construction projects.
Cryogenic tyre recycling	Tyre recycling at low temperature using liquid nitrogen or commercial refrigerants to embrittle the rubber.
Cuts	The result of mechanical processes by which end-of-life tyres are fragmented, ripped or torn into irregularly formed pieces, typically larger than 300 mm in size.
Devulcanizate	The product of devulcanization which results in the reduction of cross-links. Rubber reclaim can be a kind of devulcanizate.
Devulcanization	The treatment of rubber that results in the reduction of cross-links.
End-of-life tyre	Another name for a waste tyre.
Fines (carbon products)	Agglomerates, pellets or pellet fragments which pass through different standardized sieves.
Fine powders	The result of processing rubber to achieve finely dispersed particles of <500 µm, including surface modified powders.
Granulate	The result of processing rubber to reduce it to achieve finely dispersed particles, typically between 0.8 mm and 20 mm.
Other tyre	A generic term including tyres used, for example, by off-road agricultural vehicles and aircraft.
Powder	The result of processing rubber and reducing it to achieve finely dispersed particles, typically under 0.8 mm.
Pyrolysis	The thermal decomposition of rubber in the absence of oxygen, chemically breaking it down into oil, gas and char. Gasification is a form of pyrolysis with the presence of limited oxygen.
Retreading	Generic term for reconditioning a used tyre by replacing the worn tread with new material. It may also include renovation of the outermost sidewall surface and replacement of the crown plies or the protective breaker.
Rubber reclaim	Rubber produced by treating a vulcanization so as to restore some of its original characteristics. The reclaimed rubber is inferior in quality to the original rubber.
Scrap tyre	Another name for a waste tyre.
Shred	The result of mechanical processes by which end-of-life tyres are fragmented, ripped or torn into irregular pieces, typically of 20–400 mm in any dimension.

Shredding	Any mechanical process (including cryogenic options) by which tyres are fragmented, ripped or torn into irregular pieces of 20–400 mm in any dimension. "Primary shredding" usually refers to the processing of end-of-life tyres by shredding, crushing or fragmenting, while maintaining in the resulting material an average global composition similar to that of end-of-life tyres.
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 waste tyres are reprocessed into products, materials or substances for any purpose. It does not include energy recovery or reprocessing into materials for use as fuels or in backfilling operations.
Used tyre	A tyre that has been subjected to any type of use and/or wear.
Waste tyre	A tyre that is disposed of or is intended to be disposed of or is required to be disposed of by the provisions of national law
Whole tyre applications	The use of whole waste pneumatic tyres, without physical or chemical treatment, for purposes such as the construction of sound barriers or temporary roads, or for stabilization.

I. Introduction

A. Background and scope

1. The parties to the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal have considered the difficulties involved in identifying and managing used and waste pneumatic tyres, given their potential harmful effects on human health and the environment. Accordingly, technical guidelines on the identification and management of used tyres were prepared. They were adopted by the Conference of Parties to the Convention by its decision V/26, with the first version published in October 2000 and reissued in November 2002.

2. In the seven years that followed the publication of these guidelines, additional knowledge and experience in handling used and waste pneumatic tyres was gained in many countries, and attention turned to technological, economic and environmental factors broader than those discussed in the original version of the guidelines. Consequently, the Conference of the Parties adopted decision VIII/17 with a view to revising and updating the guidelines, so as to assist national authorities in the environmentally sound management of used and waste pneumatic tyres within their national territories.

3. The revised technical guidelines provide guidance for the environmentally sound management (ESM) of used and waste pneumatic tyres in accordance with decisions VIII/17, IX/14 and BC-10/6 of the Conference of the Parties to the Basel Convention and VI/3 and VII/6 of the Open-ended Working Group of the Basel Convention.

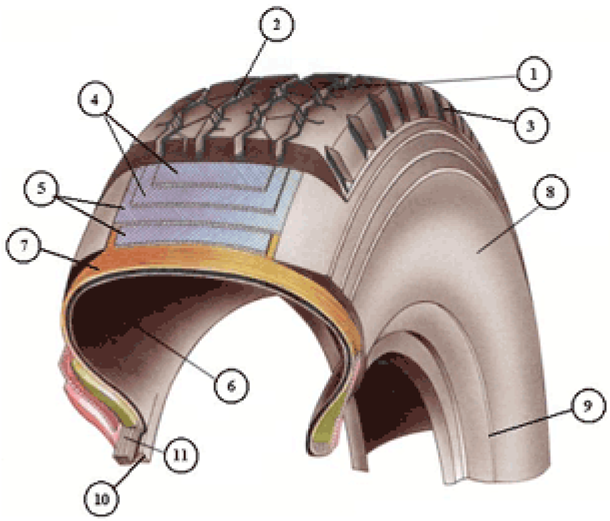
B. General properties of tyres

1. Structure: tyre components and definitions of technical terms

4. Tyres comprise components that include several parts, types of steel and rubber compounds. The definitions of these components set out in the present guidelines are intended solely as general information for those involved in operations to manage used and waste tyres. International standards and regulations, including those issued by the United Nations Economic Commission for Europe for new tyres, provide more detailed definitions.

5. The main components of a tyre, in addition to the technical terms used to enable consumers to identify its characteristics, are shown in figure I.

Figure I
Components of a tyre



Notes:
1. The most common types of tyre structure are diagonal (cross-ply), bias-belted and radial.
2. Almost 80 per cent of all tyres sold are radial tyres.
3. The sidewall of a tyre shows a range of information, depending on national legislation and the manufacturer, to enable purchasers to ensure that the tyres purchased meet their needs.

(a) **“Tread” (1)** means the portion of a pneumatic tyre designed to come into contact with the ground;

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

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

(d) **“Ply” (4, 5)** means a layer of rubber-coated parallel cords. In the radial tyre, its purpose is to stabilize the tyre;

(e) **“Cord” (6)** means the strands forming the fabric of the plies in a pneumatic tyre;

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

(g) **“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 labelling (marking), decoration or protective bands or ribs;

(h) **“Belt” (9)** refers to a radial ply or bias-belted tyre; it 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;

(i) **“Bead” (10)** means the part of a pneumatic tyre that is shaped and structured so to fit the rim and hold the tyre on to it;

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

2. Tyre composition

6. The components of a new tyre are shown in table 1, and the materials used in its manufacture 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[1] and information supplied by manufacturers of truck tyres.

7. Varying service conditions mean that truck tyres contain more natural rubber in proportion to synthetic rubber than car tyres.

1 Life-cycle assessment of an average European car tyre (Préconsult for ETRMA, 2001).

Table 2
Materials used in the manufacture of tyres

Material	Source	Application
Natural rubber	Natural rubber is predominantly obtained from the sap of the *Hevea brasiliensis* tree.	Generally speaking, natural rubber currently accounts for about 30–40 per cent of the total elastomeric portion of a car tyre, and 60–80 per cent of a truck tyre.
Synthetic rubber	All synthetic rubbers are made from petrochemicals.	Generally speaking, synthetic rubber accounts for about 60–70 per cent of the total elastomeric portion of a car tyre, and about 20–40 per cent 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 manufactured in only a few plants around the world because of its high quality requirements.	Steel is used to provide rigidity and strength in the tyres.
Reinforcing fabrics	Polyester, rayon or nylon	Used to lend structural strength to the carcasses of car tyres.
Carbon black, amorphous silica	Carbon black is derived from oil stock. Amorphous silica is obtained from silicium and sodium carbonate. It may be of either natural or synthetic origin.	Carbon black and silica provide durability and resistance against wear and tear.
Zinc oxide	Zinc is a mined mineral. It may also be derived from recycled zinc, which then undergoes a production process to produce zinc oxide.	Zinc oxide is added essentially as a vulcanization activator. After vulcanization it is present in tyres as bound zinc.
Sulphur (including compounds)	This is a mined mineral, which may also be extracted from gas or oil.	Main actor in vulcanization
Resorcinol Formaldehyde		Components of the adhesive systems used for bonding rubber to the textile fibres and for improving the adhesion between rubber and the brass-plated steel belt.
Oils: Aromatic oil, MES (special purified, aromatic oil), Naphthenic oil, TDAE (special purified aromatic oil) , Paraffinic oils		
Other additives and solvents Heterocyclic compounds, Phenylene-diamine derivatives, Phenolic stabilizers, Sulphenamides, Guanidine derivatives, Thiazoles, Dithiophosphates, Thiurams, Dithiocarbamates, Thioureas,	Synthetic or natural sources.	Other additives are used in the various rubber compounds to modify handling, manufacturing and end-product properties. Age resistors, processing aids, accelerators, vulcanizing agents, softeners and fillers.

Material	Source	Application
Others		
Recycled rubber	Recovered from waste 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), ETRMA (2001) and "State of knowledge report for tire materials and tire wear particles", ChemRisk Inc. (30 July 2008).

3. Physical properties of tyres

8. Tyres vary in weight according to their composition and use. Table 3 provides information on the three commonest 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	91
Truck	52.5	19

Source: Hylands and Shulman (2003).

9. According to the German cement industry, the heating value of used tyres for co-incineration is 26 MJ/kg (VDZ 2008).[2] This value is confirmed in UBA (2006),[3] where the average heating value for used tyres as secondary fuel is 25.83 MJ/kg.

10. Table 4 provides information on the energy content and carbon dioxide emissions of various fuels.

Table 4
Energy content and carbon dioxide emissions of fuels

Fuel	Energy (GJ/t)	Emissions ($kgCO_2/t$)	Emissions ($kgCO_2/GJ$)
Tyres	25–35	2,72	85
Carbon	27	2,43	90
Petroleum coke	32.4	3,24	100
Diesel oil	46	3,22	70
Natural gas	39	1,989	51
Wood	10.2	1,122	110

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

11. Calorific value and other parameters depend on the origin of the tyres (car/truck), usage ratio (remaining rubber), physical aspect (shredded or not), and vary by country and producer.

12. Tyres cannot spontaneously combust and are therefore not classified as flammable pursuant to characteristics H4.1–4.3 of Annex III to the Basel Convention. Work carried out by the Building Research Establishment in the United Kingdom of Great Britain and Northern Ireland[4] using tyre bales gave the following results:

(a) The minimum temperature for ignition was 182º C, when the temperature was maintained at 182° C for 65.4 days;

2 VDZ (2008).
3 UBA (2006).
4 HR Wallingford (2005).

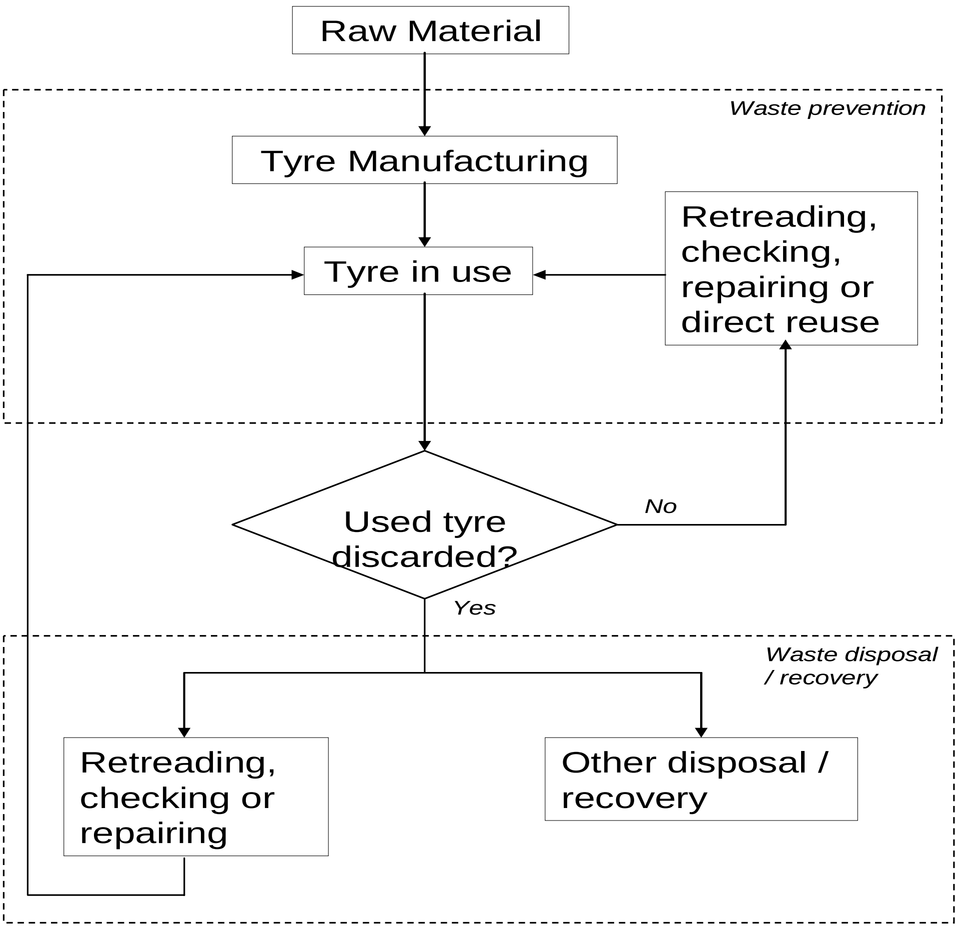
(b) Short-term spontaneous ignition will only occur after exposure to a temperature of 350° C for five minutes or a temperature of 480° C for one minute.

13. It is worth pointing out, however, that natural phenomena (such as lightning, if tyres are not properly stored) and deliberate human acts (e.g., arson and balloons) can produce conditions conducive to tyre combustion. Once alight, these fires are difficult to control because of the heat generated. A list of fires that have occurred in waste-tyre stockpiles is found in appendix III to the present guidelines.

C. Stages in the life of a tyre

14. The various stages in the life of a tyre, from when raw material is acquired through to manufacture, use and disposal, are shown in figure II. It shows in particular that retreading may take place in the prevention phase as a re-use measure or in the waste recovery/disposal phase where tyres that have been discarded may undergo retreading or other environmentally sound disposal operations, thus increasing the useful life of tyres through retreading in both phases.

Figure II
Stages in the life of a tyre



1. Used pneumatic tyres

15. Some countries allow the resale of used, partly worn tyres for their original purpose. It is worth pointing out, however, that used tyres should be purchased with great care, as there are risks involved.

Such tyres could have originated from vehicles that had been involved in accidents, damaged by potholes or other obstacles, used without the appropriate pressure calibration or incorrectly repaired.

16. Used, partly worn tyres can be reused without further treatment. Sources of such tyres include:

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

(b) Old (out-of-date) tyres that are used for less demanding applications;

(c) Tyres that are exchanged for reasons other than that of having reached the end of their life, such as the vehicle owner's fitting a set of high-performance tyres or new wheels.

17. The United Kingdom has legislation governing the sale and distribution of used tyres that forms part of its 1994 motor vehicle tyres safety regulations. The requirements for selling and distributing these tyres are as follows:

(a) There must not be any cut in the tyre exceeding 25 mm or 10 per cent of the 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 must not have any external lump, bulge or tear caused by a separation or failure of its structure;

(c) No part of the ply or cord of the tyre must be exposed, either internally or externally;

(d) When inflated to the maximum pressure at which it is designed to operate, the tyre must not show any of the defects described above;

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

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

18. Studies are under way to equip tyres with electronic chips called radio frequency identification devices to record information about the conditions in which they are used. If their efficiency can be demonstrated, such devices may prove effective in identifying the correct parameters for reusing used tyres.

2. Retreaded tyres

19. The term "retreading" refers to replacing the wearing surface of the tyre. The retreading process is considered as a way of increasing the useful life of tyres and may be considered a reuse measure within the waste management hierarchy. Further information on retreading technologies is presented in section F of chapter III of the present guidelines.

20. Where tyres that have been previously discarded are retreaded, retreading is a waste recovery operation. Where used tyres that have not been discarded are retreaded, retreading is a form of waste prevention. In both cases retreading enables the tyres to be reused and extends their useful life.

3. Waste pneumatic tyres

21. Waste pneumatic tyres may be retreaded for further use or can be recovered by being cut, shredded or ground and then used in several applications, such as footwear, sportsground surfaces and carpets. They can also be used in the form of tyre-derived fuel for energy recovery.

D. Potential risks to health and the environment

22. Tyre components have no hazardous properties and are therefore not intrinsically hazardous. If, however, they are improperly managed and disposed of, they may pose risks to public health and the environment.

23. Tyres are not biodegradable because the time that they take to decompose is indeterminate. Used tyres represent waste that takes up much physical space and is difficult to compact, collect and eliminate. In addition to the visual impact, inadequate disposal can block water channels, creeks and storm water drains, resulting in changes in flow patterns. These changes can lead to erosion, the silting up of water flows, and contribute to increasing flooding rise.

24. Prone to heat retention and owing to their own open structure, piled tyres increase the risk of fires, by arson or due to accidental causes such as lightning, which, once ignited, are difficult to

control and put out. Tyre fires can burn for months, generating smoke, oil and lechate toxic contaminants that affect the soil, waterways and air. [5] In landfills, tyres occupy valuable space, represent a fire hazard, are not biodegradable, and frequently rise to the surface, creating a new set of landfill management concerns.[6] It is for this reason that tyres have been banned from disposal in landfills in the European Union.[7]

25. More detailed information about public health aspects is given in appendix I.

1. Risks to public health

26. Unless properly managed, waste pneumatic tyres represent ideal homes for rodents and breeding sites for mosquitoes that transmit dengue and yellow fever. This is especially relevant in tropical and subtropical regions. The round shape of tyres, together with their impermeability, enables them to hold water and other debris (e.g., decaying leaves) for long periods, making them ideal places for mosquito larvae to develop. Their relative importance by comparison with other breeding sites remains unknown and may depend on local circumstances. It should be noted that these larvae also breed in other human-created containers such as discarded plastic food containers, earthenware jars, metal drums and concrete cisterns used for domestic water storage.

27. Waste tyres are especially likely to facilitate the spread of the mosquito species *Aedes aegypti* and *Aedes ablopictus*, the principal vectors of dengue and yellow fever, diseases that afflict millions of people in tropical regions. In temperate regions, species such as *Aedes triseriatus* and *Aedes atropalpus* are more predominant.

28. When transported, used tyres not only spread mosquitoes that are otherwise limited in their reach, but also contribute to the introduction of non-native species, which are often more difficult to control, thereby increasing the risk of disease. The rapid spread of *Aedes ablopictus*, in particular, has been attributed largely to the international trade in used tyres.

29. *Aedes ablopictus* (the Asian tiger mosquito or forest day mosquito) was first introduced into the south-eastern United States of America in the late 1980s, through the import of used tyres from Asia. It spread rapidly along north-south transportation routes, aided by the movement of goods and people, and in some areas has displaced native species of mosquitoes. The mosquito has been found as far north as Chicago, but it does not survive the winters in the northern United States. It has never been identified in Canada.[8]

30. This evidence demonstrates conclusively that the uncontrolled accumulation and inappropriate transport of used and waste tyres pose a genuine risk of diseases being transmitted by mosquitoes. Companies involved in transport and management should be aware of this and handle tyres in such a way as to reduce the spread of disease. Appendix I provides further information about the diseases in question and the measures that companies can take.

31. Chapter 5 of the World Health Organization publication: *Dengue haemorrhagic fever: diagnosis, treatment, prevention and control*,[9] on vector surveillance and control, states that the most effective means of vector control is environmental management. This includes planning, organizing, carrying out and monitoring activities for the modification or manipulation of environmental factors, with a view to preventing or reducing vector propagation and human-vector-pathogen contact. A significant contributor to such contact is the fact that in urban areas waste is often not collected and instead abandoned close to housing areas. Moreover, used tyres are often used by the population for such purposes as planting flowers, providing ballast on roofing and manufacturing toys for children. These tyres may then become breeding sites for mosquitoes. Filling, covering or collecting the tyres for recycling or disposal are suggested as means of vector surveillance and control in these cases. This shows the importance of raising awareness and of having a sound and functional system for collecting and managing tyres.

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

6 Directive 1999/31/CE.

7 Directive 1999/31/EC refers to the deposition of tyres in landfills and supports this paragraph.

8 Health Canada.

9 WHO, second edition (1997).

2. Environmental risks

32. The environmental impact of various technologies and methods for treating tyres, and the environmentally sound disposal of tyres, are discussed in section F of chapter III of the present guidelines. This general section on the potential environmental risks associated with tyres discusses the more cross-cutting issues of ecotoxicity, leaching and the potential impact of uncontrolled fires. The technologies involved, the main environmental problems associated with them and suggested ways of avoiding them are covered in the annex to the present guidelines.

(a) Ecotoxicity

33. The ecotoxicity of used and waste tyres is challenging to evaluate. The ecotoxicity related to tyres is linked to particles resulting from the use of tyres, to uncontrolled dumping and to disposal operations. Conclusions regarding the toxicity and risks to human health from diverse studies vary significantly. Given the broad range of substances found in tyres many parameters influence the results of studies such as the type of tyres evaluated, the chemicals assessed and the evaluation methodology. Gaps remain in the scientific knowledge regarding the ecotoxicity of tyres. The following studies present some of the conclusions.

34. In 1995, studies were conducted by the Pasteur Institute in Lille, France, on the use of rubber powder obtained from tyre carcasses with algae (*S. Capricornutum and crustacean: Daphnia magnia and Fish Brachydanio rerio*), according to International Organization for Standardization standards ISO 8692, 6341 and 7346. A supplemental study was conducted, also by the Pasteur Institute, this time in Lyon, France. This study was called "*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*". None of the tests revealed toxicity.

35. In 2003, tests conducted by Birkholz in California[10] using rubber fragments taken from a tyre-disposal site showed toxicity for bacteria, invertebrates, fish and green algae. After three months, new samples were tested, showing a 59 per cent reduction in the toxicity levels detected in previous tests.

36. In addition to acute or short-term toxicity, long-term studies should also be taken into account. Long-term investigations indicate that some types of tyres, e.g., those with high aromatic oil content, may under specific conditions leach significant amounts of polycyclic aromatic hydrocarbons into the aquatic environment,[11] thereby influencing the population dynamics of wood frogs, for example.[12]

37. In 2005, Wik and Dave conducted a study to investigate whether toxicity testing with Daphnia magna according to ISO 6341 could be used as a screening test for environmental labelling of car tyres. The background issue being considered was potential toxic effects of tyre wear particles on aquatic organisms (which is different from the studies mentioned in paragraph 33 about the leaching of chemicals from artificial turf systems). The toxicity to Daphnia magna from 12 randomly selected car tyres was tested in this study, especially with reference to HA oils. Rubber from the tread of the tyres was grated into small pieces to simulate material from tyre wear. The results show that all tyres tested in this study were toxic to Daphnia magna after 24-hour and 48-hour exposure and that exposure from different tyres can vary in toxicity by 2 orders of magnitude. Given that this variation was found for 12 randomly selected tyres, the overall variation between all tyres on the market is expected to be considerably larger. The difference in toxicity in summer and winter was substantial.[13]

38. Previous studies have indicated that tyre tread particles are toxic to aquatic species, but few studies have evaluated the toxicity of such particles using sediment, the likely reservoir of tyre wear particles in the environment. In this study, the acute toxicity of tyre and road wear particles (TRWP) was assessed in Pseudokirchneriella subcapita, Daphnia magna and Pimephales promelas using a sediment elutriate (100, 500, 1000 or 10,000 mg/l TRWP). Under standard test temperature conditions, no concentration response was observed and EC/LC(50) values were greater than 10,000 mg/l. Additional tests using Daphnia magna were performed both with and without sediment in elutriates collected under heated conditions designed to promote the release of chemicals from the rubber matrix to understand what environmental factors may influence the toxicity of TRWP. Toxicity was only observed for elutriates generated from TRWP leached under high-temperature conditions and the lowest EC/LC(50) value was 5,000 mg/l. In an effort to identify potential toxic chemical constituent(s)

10 California Integrated Waste Management Board (CIWMB) (2007).

11 Stephensen, Eiríkur and others (2003).

12 Camponelli, Kimberly M. and others (2009).

13 Wik A. and Dave G. (2005).

in the heated leachates, toxicity identification evaluation (TIE) studies and chemical analysis of the leachate were conducted. The TIE coupled with chemical analysis (liquid chromatography/mass spectrometry/mass spectrometry [LC/MS/MS] and inductively coupled plasma/mass spectrometry [ICP/MS]) of the leachate identified zinc and aniline as candidate toxicants. However, based on the high EC/LC(50) values and the limited conditions under which toxicity was observed, TRWP should be considered a low risk to aquatic ecosystems under acute exposure scenarios.

(b) Leaching

39. Water generated by tyre leachate may contaminate soil, surface water and groundwater at the site and surrounding areas. On the basis of specialist literature and its own experience, the Ministry of the Environment of New Zealand[14] has identified several factors that may affect the rate of leaching and/or the concentration of tyre leachate compounds in soil, surface water and groundwater.

40. Other studies show that leaching of heavy metals and organic chemicals such as phthalates and polycyclic aromatic hydrocarbons from recycled car tyres for use as infill in artificial turf systems is well within the limits set in the Netherlands for soil and surface water quality. Leaching of zinc is an exception. Dissolved organic carbon and organic nitrogen appear to decrease very rapidly at the outset and are then minimized in a time-dependent, substance-specific manner. During testing, very low polycyclic aromatic hydrocarbon concentrations of the granules were found at an identical level in the blank sample (a gravel layer without a surface); these correspond to ambient (ubiquitous) contamination levels. Appendix II provides information on fieldwork conducted to study tyre leachate.

41. Three recent studies have examined the environmental aspects of using tyre granulates as filler for synthetic games fields.[15] These studies researched the elements and chemical substances found in the composition of the filling materials, and more particularly those made from used tyres. The exhaustive list comprises forty-two physicochemical parameters: total cyanides, phenol index, total hydrocarbons (HCT), 16 polycyclic aromatic hydrocarbons (PAH), total organic carbon (TOC), Al, As, Ba, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Sb, Se, Sn, Zn, fluorides, nitrates, ammonium, chlorides and sulphates, pH and conductivity. The studies concluded that the physicochemical results of the percolates showed a kinetic pattern for potentially polluting substances, independently of the type of granulates used in either in-situ or in-lab tests. Analytically detectable trace substances or compounds are dissolved from the surface and from the polymer matrix of the granules in a concentration that falls over time. The concentrations of the measured individual substances, the dissolved organic carbon and the organic nitrogen decrease very rapidly at the outset, subsequently slowing to a minimum in a time-dependent, substance-specific manner, in both the lysimeter trials and the elute tests. According to current research, after a year’s experimentation, the results from 42 physico-chemical parameters and ecotoxicological tests show that water passing through artificial turf using as filling either virgin elastomers granulated or granulates from used tyres is not likely to affect water resources in the short and medium term.

42. In the 2007 study conducted by Wik, a novel approach was used to identify toxic components that leach from tyre rubber when in contact with water. Rubber formulations containing different tyre additives were prepared and water leachates from these rubber samples were generated and tested on Daphnia magna, using a standardized toxicity test. Findings from this study showed that the choice of chemical additives in tyre rubber greatly affects the toxicity of the leachate and that this should be taken into consideration in future developments of rubber for tyres to reduce their potential environmental impact.

43. As regards the assessment of the long-term impact of the leaching of zinc from artificial turf, three INTRON studies conducted in 2008 and 2009 provide useful information.[16] One of the studies intended to answer the question of whether zinc leaching from rubber infill posed a risk to the environment in the long term and also assumed an increasing zinc release due to aging of the rubber**.** The study was performed by SGS INTRON and reviewed by Verschoor and Cleven from the Dutch National Institute for Public Health and the Environment (RIVM). The results of this study show that the limit values in the present Dutch Soil Quality Decree will be reached after more than 60 years for a sports system consisting of artificial turf with rubber infill, lava sublayer and sand base layer and after 7 to 70 years for a sports system consisting of only the artificial turf with rubber infill and the lava sublayer. The 2008 monitoring results show that the concentrations of zinc are low both in drainage water and rainwater. There is no systematic difference in the concentration of zinc in rainwater and the

14 MWH (July 2004).

15 Aliapur and others (2007).

16 INTRON report A845090/R20090029, “Adsorption of zinc to synthetic turf underlays” (2009).

concentration of zinc in drainage water. On the basis of the new observations, INTRON concludes that, after 7 years of use, zinc does not penetrate the underlays. This is consistent with the laboratory tests performed in the 2009 zinc adsorption study where calculations were updated based on the actual adsorption capacity of the sand layer instead of a theoretical one used in the previous study. After 7 years, there is also no evidence that the use of rubber infill poses a risk in terms of the leaching of zinc and the results indicate that during the technical lifetime (fifteen years) of the synthetic turf field, with environmentally sound management, there is limited risk to the environment due to the leaching of zinc.

44. According to current research, after a year's experimentation, the results from the 42 physicochemical parameters identified and from the ecotoxicological tests showed that water passing through artificial turf in which the filler was either granulated virgin elastomers or granulates from used tyres was not likely to affect water resources in the short and medium terms.[17]

45. Some literature on the potential of chemicals to leach from used tyres concluded that the impact of used tyres on the subsoil of roads or surface water under neutral environmental conditions was negligible with regard to groundwater and surface water quality and the aquatic environment.[18]

(c) Uncontrolled open air burning

46. Tyres do not spontaneously combust. If, however, a fire breaks out, either as a result of arson or accidentally, the composition of a pile of tyres will affect the fire's rate and direction. Fires occurring in piles of complete tyres tend to burn down into the middle of the pile, where air pockets allow for continued combustion. Fires occurring in piles of chipped or shredded tyres tend to spread over the pile's surface.

47. Various decomposition products are generated during the combustion process, including:

(a) Ash (typically containing carbon, zinc oxide, titanium dioxide, silicon dioxide, cadmium, lead and other heavy metals);

(b) Sulphur compounds;

(c) Polycyclic aromatic hydrocarbons (PAHs);

(d) Aromatic oils;

(e) Carbon and nitrogen oxides;

(f) Particulates;

(g) Various light-end aromatic hydrocarbons (such as toluene, xylene and benzene).

48. Fire decomposition products are extensive and vary as a function of factors including:

(a) Type of tyre;

(b) Burn rate;

(c) Size of tyre piles;

(d) Temperature of the environment;

(e) Humidity.

49. Some fire decomposition products, in particular those resulting from incomplete combustion, are persistent organic pollutants. The reduction or elimination of unintentional emissions of such substances is regulated by Article 5 of and Annex C to the Stockholm Convention on Persistent Organic Pollutants.

50. In France, the rubber manufacturers' association has performed a number of field experiments to determine the composition of smoke from fires affecting tyres in warehouses in which they are stored, both with and without sprinklers.[19] Table 5 describes the composition of the smoke.

17 Aliapur and others (2007).

18 Literature study on substances leached from shredded and whole tyres (published June 2005 by the European Association of the Rubber Industry (BLIC)).

19 Incendie dans un entrepôt de stockage de pneumatiques équipé d'une installation sprinkler. Impact environnemental sur l'air et sur l'eau (SNCP, 2007).

Table 5
Composition of smoke from tyre fires

Component	Production in non-sprinkler installation (g/kg of tyre burned)	Production in installation with sprinkler (g/kg tyre burned)
Carbon dioxide	1450	626
Carbon monoxide	35	42
Nitrous oxide	0.9	0.75
Nitric oxide	3.2	1.6
Sulphur dioxide	15	4
Cyanhydric acid	4	0.6
Hydrochloric acid	Not detected	2
Total unburned organics (including benzene and toluene, in toluene equivalents)	23	61
Dust	285	20
Metals (total) including aluminium and zinc >99%	31.9	22.74
Polycyclic aromatic hydrocarbons (total)	0.0633	0.093
Polychlorinated biphenyls (total)	2.66×10^{-4}	2.16×10^{-5}
Dioxins/furans (total	6.44×10^{-7}	1.9×10^{-7}
Components looked for but not detected (below analytic detection limit)	Formaldehyde hydrochloric acid, hydrobromic acid, acrolein, ammonium, tin	Formaldehyde, hydrobromic acid, acrolein, ammonium, tin

51. Because of the lower temperature, fires controlled by sprinklers have higher emissions of carbon monoxide and unburned organics. Emissions of other substances are lower, especially dust, which is washed out of the smoke. The observed concentrations of polychlorinated biphenyls and dioxins and furans are normally comparable to those observed in ambient air. This may be different for large stockpiles of tyres or monolandfills for tyres.

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

(i) Air pollution

53. Tyre fires in the open air emit black smoke, carbon dioxide (contributing to the greenhouse effect), volatile organic compounds and hazardous pollutants, such as polycyclic aromatic hydrocarbons, dioxins, furans, hydrochloric acid, benzene, polychlorinated biphenyls, arsenic, cadmium, nickel, zinc, mercury, chromium and vanadium.[20]

54. The leachate of such pollutants with rainwater may also lead to soil and water contamination. This may occur through two 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).

(ii) Water pollution

55. If burned, 1 million tyres will generate some 200,000 litres of run-off oil, as tyre combustion causes pyrolysis of the rubber, which results in oily decomposition waste that is both highly polluting and flammable. In addition to the problems caused by oil run-off, the waste may be carried by water, if it is used to extinguish the fire, or via percolation through the soil, reaching the groundwater or nearby streams. Other residues of combustion, such as zinc, cadmium and lead, can also be washed away by water. Contaminants such as arsenic, benzene, mercury, copper, dioxins, polychlorinated biphenyls and polycyclic aromatic hydrocarbons may also be present.

20 Reisman, Joel I. (1997).

(iii) Soil pollution

56. Residues left in the soil after a fire may cause immediate pollution as a result of liquid decomposition products penetrating the soil, or gradual pollution as a result of leaching of ash and other unburned residues. Both are caused mainly by rainfall and water penetration at the site.

II. Relevant provisions of the Basel Convention

A. General provisions

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

58. 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, it defines disposal as "any operation specified in Annex IV" to the Convention. In paragraph 8, it defines the environmentally sound management 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".

59. 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)".

60. Article 4, paragraphs 2 (a)–(e) and (g), contains the key provisions of the Basel Convention pertaining to environmentally sound management, waste minimization, and waste disposal practices that mitigate adverse effects on human health and the environment. The relevant provisions are:

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. Provisions relevant to tyres

61. Article 1 ("Scope of the Convention") defines the types of waste subject to the 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 one of the categories of 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").

62. One important element 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 specific waste to be "hazardous" for the purpose of the Convention, pursuant to its national legislation. In this case, the country needs to notify the Secretariat of the content of its national legislation, and the Secretariat in turn will notify the other parties to the Convention that the transboundary movement of such waste is prohibited.

63. Tyres per se cannot be identified under any category of waste streams in the first part of the Annex I to the Convention (categories Y1–Y18), although they do contain elements or compounds listed in that annex. These are encased in the rubber compound or may be present as an alloying element; they are shown in table 6.

Table 6
Annex I constituents contained in tyres

Convention constituent	Chemical name	Remarks	Content (%weight)	Content * (Kg)	Applicability of 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 listed 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	Complete tyres do not present any of the characteristics H1 – H12 contained in Annex III. H13 is only assessed for leaching of zinc not in excess of thresholds (see chapter III)
Y26	Cadmium	On trace levels, as cadmium compounds attendant substance of zinc oxide	Max. 0.001	Max. 0.07 g	Not in a quantity identified as giving to the waste any characteristic contained in Annex III
Y31	Lead compounds	On trace levels, as attendant substance of zinc oxide	Max. 0.005	Max. 0.35 g	Not in a quantity identified as giving to the waste any characteristic contained in Annex III

Convention constituent	Chemical name	Remarks	Content (%weight)	Content * (Kg)	Applicability of 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 a hazardous acid under the terms of Annex I Y34
Y45	Organohalogen compounds other than substances in Annex I to the Convention	Halogen butyl rubber	Content of halogens Max. 0.10	Content of halogens Max. 7 g	Not having characteristics pursuant to Annex III

64. Wastes contained in Annex I to the 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 Convention.

65. List A of Annex VIII to the Convention describes wastes that are “characterized as hazardous under Article 1 paragraph 1 (a) of the Convention” although the “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 that “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”.

66. 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 Convention.

67. Annex IX entry B3140 pertains to waste pneumatic tyres, excluding those destined for Annex IVA operations. Some countries have prohibited the import of used and waste tyres.

III. Guidance on environmentally sound management

A. General considerations

68. At present, ESM is a broad policy concept without a clear universal definition. However, provisions pertaining to ESM as it applies to used and waste tyres under the Basel Convention, and the Organization for Economic Cooperation and Development (OECD) core performance elements (discussed in the following three subsections), provide international direction that is supportive of ESM efforts under way in different countries and industrial sectors.

1. Basel Convention

69. In its Article 2 (“Definitions”), paragraph 8, the Basel Convention defines 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 adverse effects which may result from such wastes.”

70. Article 4 (“General obligations”), paragraph 2 (b), requires that each Party take appropriate measures to “ensure the availability of adequate disposal facilities for the environmentally sound management of hazardous or other wastes, that shall be located, to the extent possible, within it, whatever the place of their disposal,” while paragraph 2 (c) requires each Party to “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.”

71. 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”. The present guidelines are intended to provide a more precise definition of environmentally sound management in the context of used and waste tyres, including appropriate treatment and disposal methods.

72. The 1994 framework document on the preparation of technical guidelines for the environmentally sound management of wastes subject to the Basel Convention sets forth the principles used by countries in their waste management strategies, among which the following should be noted:

(a) *Source reduction principle*: the generation of wastes should be minimized both in terms of quantity and in terms of their potential for causing pollution. This can be achieved through appropriate processes and facilities;

(b) *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;

(c) *Precautionary principle*: preventive measures should be taken, considering the costs and benefits, of action and inaction, when there is a scientific basis, however limited, for believing that the emission of substances, wastes and energy into the environment could possibly result in injury to human health and the environment;

(d) *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 further away from their sources of origin;

(e) *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;

(f) *Polluter-pays principle*: potential polluters should take steps to avoid pollution, and those who pollute should pay to solve the problems created by pollution;

(g) *Sovereignty principle*: each country should take into consideration its own 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 legislation;

73. In the present guidelines, “disposal” is considered to be any operation specified in Annex IV to the Basel Convention, which is also included in its text under Article (“Definitions”), including sections A and B. It is noted that in some countries other definitions are used, such as “disposal” for the operations themselves and “recovery” for recovery, recycling, reclamation, direct re-use or alternative use operations.

74. The present guidelines do not include the term “closed loop recycling” as a possible disposal operation, given that, in the case of tyres, it is impossible to transform the materials of a used tyre into new tyres because, unlike paper, metals, plastics and glass, it is impossible to obtain from tyres materials with properties similar to those of the original materials used in production. The rubber materials used in tyres have specific qualities that are quite complex, designed to optimize traction on dry and wet roads, and ensure long and useful life, low rolling resistance, comfortable handling with good response to steering and good performance at a relatively low cost. Unfortunately, the recycled products currently available do not improve on performance and are costlier. With car tyres there are effects that are particularly detrimental to durability and rolling resistance (associated with fuel consumption). The quantity of these post-consumer recycled materials will therefore inevitably be very low.[21]

75. Several key principles with regard to the environmentally sound management of waste were set out in the above-mentioned 1994 framework document. To achieve the environmentally sound management of wastes, the framework document recommends that a number of legal, institutional and technical conditions (environmentally sound management criteria) be met, and in particular that:

21 California Environmental Protection Agency (United States of America), “Integrated Waste Management Board, Increasing the Recycled Content in New Tyres 21” (2004).

(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 indicates that the management of hazardous wastes has resulted in unacceptable discharges;

(e) People involved in the management of hazardous wastes are capable and adequately trained in their capacity.

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

77. 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;

(c) Provision of sites or facilities authorized as environmentally sound to manage wastes and, in particular, hazardous wastes.

2. Core performance elements for the environmentally sound management of waste

78. In May 2004, theOECD Council adopted recommendation C (2004)100[22] on the environmentally sound management of wastes. According to that recommendation, 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 should 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-sized enterprises, the type and amount of waste, the nature of the operation and domestic legislation, as part of their core performance requirements waste management facilities should:

(a) Have an applicable environmental management system in place;

(b) Take sufficient measures to safeguard occupational and environmental health and safety;

(c) Have an adequate monitoring, recording and reporting programme;

(d) Have an appropriate and adequate training programme for personnel;

(e) Have an adequate emergency plan;

(f) Have an adequate plan for closure and after-care.

Further information can be found in the guidance manual for the implementation of the recommendation,[23] which includes the core performance elements.

22 OECD (2004).

23 OECD (2007).

B. Legislative and regulatory framework

79. Parties to the Convention should examine national controls, standards and procedures to ensure that they fully implement their obligations under the Convention, including those pertaining to the transboundary movement and environmentally sound management of used and waste tyres.

80. 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 environmentally sound management and require adherence to those principles, ensuring that countries satisfy provisions for the environmentally sound management of used tyres, including their environmentally sound disposal, as described in the present guidelines.

1. Transboundary movement requirement

81. Hazardous and other wastes should, as far as is compatible with their environmentally sound management, be disposed of in the country in which they were generated. Transboundary movements of such wastes are permitted only:

(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 lacks 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.

82. According to Article 6 of 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 are to prohibit the export of hazardous and other wastes if the country of import prohibits their import. The Convention also requires that information regarding any proposed transboundary movement be provided using the accepted notification form, and that the approved consignment be 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.[24]

83. When transboundary movement of hazardous and other wastes for which consent has been given by the countries concerned cannot be completed, the country of export is to 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 is to ensure that the wastes in question are taken back into the country of export for their disposal, or are disposed of in accordance with the provisions of the Convention.

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

C. Management approaches to used and waste pneumatic tyres

85. Although tyres are consumer goods that are currently essential to any country's economy, inappropriate disposal can affect the environment and human health. As waste generation is unavoidable, it is essential that sound management systems be implemented to minimize waste generation while maximizing reuse and recycling, and the energy and material recovery of waste tyres.

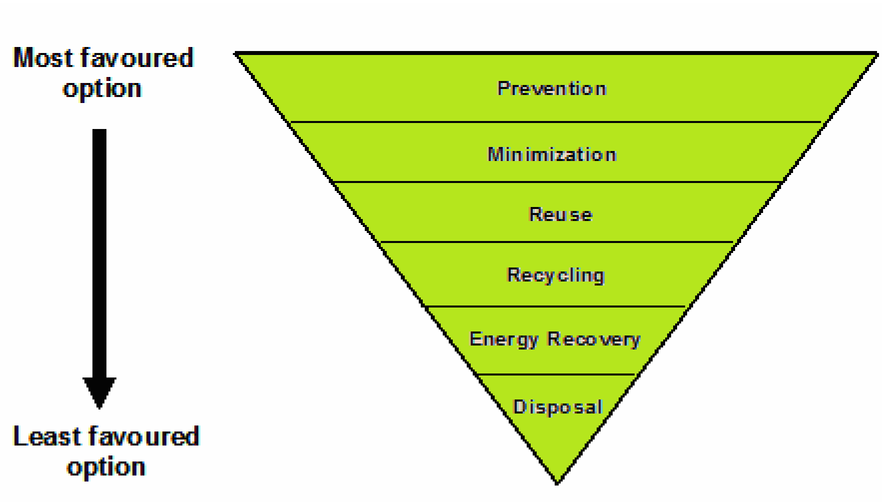
1. General considerations

86. The Basel Convention obliges parties to ensure the environmentally sound management of hazardous and other wastes. In this regard, the guiding principle broadly accepted for securing a more sustainable waste management system is the waste hierarchy of management practices, which accords

24 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.

priority to waste prevention and reuse followed by recycling and other recovery operations over disposal. The waste management hierarchy, as shown in figure III below, should apply as a priority order in waste prevention and management legislation and policy to avoid undesirable impacts on the environment and human health.

Figure III
Used and waste tyre management hierarchy



87. Prevention and minimization measures are presented in section D of chapter III. Reuse is addressed in, inter alia, section C of chapter I and in this section. Environmentally sound disposal is covered in section F of the same chapter and may be grouped into the following categories:

(a) Retreading;

(b) Ambient/cryogenic recycling;

(c) Devulcanization and reclaim;

(d) Industrial and consumer products;

(e) Civil engineering;

(f) Pyrolysis;

(g) Co-processing;

(h) Co-incineration in plants for electric power generation.

88. All other existing processes for disposing of used and waste pneumatic tyres could generate negative environmental impacts and are therefore not considered to be environmentally sound.

2. Environmental management systems

89. An environmental management system comprises a set of processes and practices that enable an organization to reduce its environmental impacts and increase its operating efficiency. It is as a tool to improve environmental performance and includes the organizational structure, planning and resources for developing, implementing and maintaining a policy for environmental protection. Such a system provides consistency for organizations to respond to environmental concerns through the allocation of resources, assignment of responsibility and continuing evaluation of practices, procedures and processes. In many cases, the introduction of such a system can lead to cost savings and reduced environmental liability.

3. National systems for managing used and waste pneumatic tyres

90. Systems in use for managing used and waste pneumatic tyres include those described below. Table 7 shows the management systems adopted in a number of countries for used and waste tyres.

(a) Producer responsibility

91. "Extended producer responsibility" (EPR) is defined as an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle. A "producer " is considered to be brand owner or importer except in cases such as packaging, and in situations where the brand owner is not clearly identified, as in the case of electronics, the manufacturer (and importer) would be considered as the producer (OECD, 2001a). EPR programmes shift the responsibility for end-of-life management of products to the producer who puts the product for the first time on the market and away from municipalities, and provide incentives for producers to incorporate environmental considerations in the design of their products so that the

environmental costs of treatment and disposal are incorporated into the cost of the product. EPR can be implemented through mandatory, negotiated or voluntary approaches. Take-back collection programmes may be part of EPR programmes.

92. Depending on their design, EPR programmes can achieve a number of objectives: (1) relieve local government of the financial and, in some cases, the operational burden of the disposal of the waste, products or material; (2) encourage companies to design products for reuse, recyclability and materials reduction (in terms of quantity and hazardousness); (3) incorporate waste management costs into the product price; (4) promote innovation in recycling technology. This promotes a market that reflects the environmental impact of products (OECD 2001a). Detailed descriptions of EPR schemes are available in several OECD publications.

93. Environmental authorities should develop regulatory frameworks setting out the responsibilities of relevant stakeholders, standards for mercury contents and management of products, and components of EPR programmes, encouraging participation by relevant parties and the public. They should also be responsible for monitoring the performance of EPR programmes (e.g., the amount of wastes collected, amount of mercury recovered and costs accrued for collection, recycling and storage) and recommending changes as necessary. The responsibility should be placed on all producers of the products considered. Free riders (producers who do not assume their share of responsibility) should not be allowed as this forces other producers to bear costs that are disproportionate to their product market share.

(b) Tax-based system

94. In this system, producers or consumers pay a tax to the Government. The State is then responsible for organizing a system to collect and dispose of waste tyres, which is implemented, for example, by contracting operating companies that are paid through the funds raised from the tax.

95. By way of example, agencies of the individual states of the United States regulate waste tyre management, rather than the federal Government. Most states levy a consumer tax on tyre sales that supports the state management of waste tyres. Some states spend considerable amounts on implementing waste tyre programmes, while a few leave it to the free market to provide for the collection and eventual disposal of waste tyres.

(c) Free-market-based system

96. In a free-market-based system, the last owner of the tyre is responsible for its disposal or recovery. In addition, legislation may set forth goals to be attained, but may 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 7
Systems for managing the collection and sorting of tyres adopted in various countries

Producer responsibility	Tax-based system	Free-market system
Europe (Belgium, Czech Republic, Finland, France, Greece, Hungary, Italy, Netherlands, Norway, Poland, Portugal, Romania, Spain, Sweden), Turkey	**Europe** (Denmark, Latvia, Slovakia)	**Europe** (Austria, Germany, Ireland, Switzerland, United Kingdom)
Brazil, Colombia	**Canada (in the provinces), United States** (most states)	**United States** (some states)
Canada (some provinces), Israel, South Africa		**Australia**

D. Waste prevention and minimization

97. Priority should be accorded to preventing and reducing waste generation in order to increase the useful life of tyres, thereby reducing the rate at which waste is generated.

98. To that end, the guidelines and procedures for calibration and maintenance that are recommended by tyre manufacturers should be followed, and awareness-raising campaigns launched by the competent authorities. Such campaigns aim to bring home to the general public, in addition to road safety and fuel consumption issues, the importance of keeping tyres in good condition (such as keeping the optimal tyre inflation pressure), which will extend the tyres' lifespan. The use of alternatives modes of transport, such as railways and waterways, especially in countries in which such networks are developed, may be a contribution to minimizing the quantity of waste pneumatic tyres.

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

E. Collection, transportation and storage

100. Collecting, transporting and storing tyres are important phases in the management process. Collecting tyres requires logistics and planning, taking account of the diversity of points at which these tyres are generated. There is also a need to educate citizens about the benefits to be gained from delivering tyres for disposal in an environmentally sound manner.

101. To manage a used tyre in an environmentally sound manner, it should be collected at the place at which it was generated and transported elsewhere for storage.

102. Where possible, a pre-cut should be carried out during collection to improve the weight/volume ratio to reduce transportation costs.

103. Transporting used tyres from the various sources of generation to sorting facilities represents an additional cost burden, especially where there are long distances between the points of collection and sorting, because tyres take up much space in the trucks in which they are transported. Safety during transportation is another factor to be taken into account, requiring that stacking and packaging rules be strictly followed.

104. Since collection is a logistical process, optimization has to be considered on either a cost or environmental basis. Various types of optimization can be put in place, depending on the economic and legal model used. Two key types are:

(a) Collecting the maximum quantity of tyres in one run (perhaps including several stops);

(b) Collecting in such a manner that manual handling is minimized.

105. Wherever possible, using special containers to collect tyres is often the best way of achieving both a maximum quantity of tyres per run and a drastic reduction of the human resources required.

106. Sorting is necessary to separate used pneumatic tyres that can be retreaded from those that can be used for other purposes, and from waste tyres. The sorting process calls for covered facilities and a specialized workforce. Storage is also a critical issue in the collecting process. If the management of the overall flow is well controlled, storage can be treated as a transit stage before the next step in the tyre-processing chain, rather than a permanent feature.

107. To store tyres without endangering human health or the environment, the storage facility needs to meet specific requirements that are, in most cases, part of national regulations on the subject. Recommendations are available on the prevention of major risks by reducing the quantity stored per unit and by installing appropriate equipment (for examples, see table 9).

108. By way of example, some guidelines for this purpose are available in a joint publication issued by the International Association of Fire Chiefs, the Rubber Manufacturers Association and the National Fire Protection Association in 2000.

109. The following requirements must be taken into account when choosing and operating a site for storing tyres:[25]

(a) Selecting an appropriate site;

(b) Preventing and minimizing the risk of fire by implementing protection requirements and measures to reduce the spread of fires, (e.g., by setting a minimum distance between two tyre storage sites);

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

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

(e) In some countries, avoiding and controlling the breeding of mosquitoes and other disease vectors may also be relevant for the purpose of minimizing impacts on public health (see also section I.D and appendix I to the present guidelines).

25 MHW (July 2004).

110. Tables 9 and 10 and figure IV present information on best practices for the design of sites for the temporary storage recommended in the present guidelines. Figure IV shows the two most common ways of stacking tyres. Table 10 also includes a comparative overview of information provided by private associations and specialists with over 20 years' experience in the tyre reprocessing industry.[26]

111. Although the study is inconclusive regarding storage time, it is recommended that tyre storage be undertaken only when necessary and for the shortest time possible.

Table 9
Best practices for temporary storage of tyres

Criteria	IAFC, RMA and NFPA guidelines	Specialist *[27]
Storage time	NR	NR
Tyre pile maximum dimensions	6 m high / 76 m long / 15 m wide	4.5 m high / 60 m long / 15 m wide
Pile slope	NR	30º slope if naturally piled 90º slope if laced in piles (See Figure III)
Clearance in storage site	Edge of pile 15 m from perimeter fence 60 m radius from the pile should be clear of vegetation, debris and buildings	Edge of pile 15 m from perimeter fence
Fire breaks	18 m 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; concrete or hard packed clay surface; no asphalt or grass	Compacted area
Cover	N/R	Not effective
Runoff	Capture and contain	Soil bound around pile to minimize run-off of water used in fighting fires
Ignition sources	No open air burning within 300 m. No welding or other heat generating devices within a 60 m radius	NA
Water supply	63 L/s for 6hrs if tyres>1400m^3 126 L/s if storage area >1400m^3	NA
Other fire fighting resources	Foam, chemicals, fill dirt on site, access to heavy equipment/materials	NA
Fuel-fired 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 attendant	NA
Emergency vehicle access routes	Well maintained and accessible at all times. Clear width >18 m and height 4 m	NA

26 Ibid.

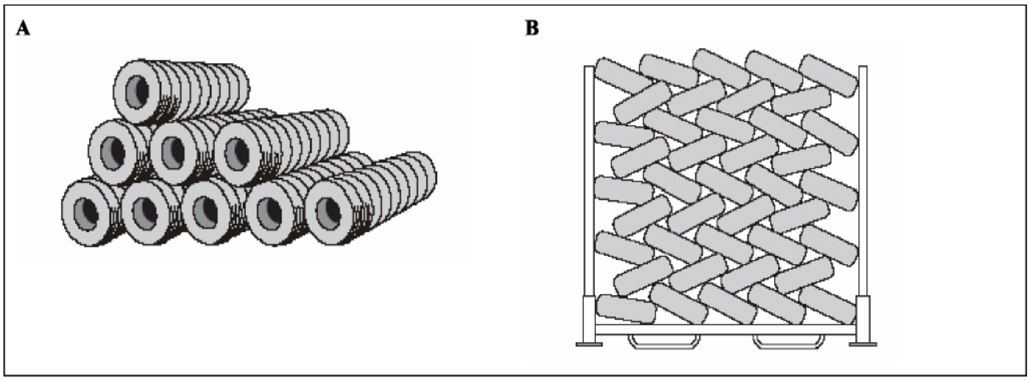
27 Specialist: Michael Playdon, Columbus McKinnon, February 2004. See bibliography for more information.

Gates at access point	6 m width at all times. Locked when closed	NA

N/R, no recommendations; NA, not asked

Source: "The Prevention and Management of Scrap Tire Fires" IAFC, STMC, NFTA (2000).

Figure IV
Most common ways of stacking 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

	Height of tyre piles (m)						
Exposed face dimension (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.

F. Environmentally sound disposal

112. The methods described in the present guidelines illustrate the most important environmentally sound disposal options and applications currently in use or under development. They respect the waste management hierarchy of reduction, reuse, recycling and energy recovery. Table 11 presents some benefits and disadvantages of environmentally sound disposal technologies, while Table 12 presents problems related to environmentally sound means of disposal together with ways of preventing and controlling them.

Table 11
Benefits and disadvantages of environmentally sound means of disposal

Means of disposal	Application/ product	Benefits	Disadvantages
Retreading	Retreaded tyre	As retreading extends the life of a tyre and uses many of the original materials and much of the original structure, the net result is a decrease in materials and energy used in comparison to the manufacture of new tyres. The energy used to retread a tyre is approximately 400 MJ, compared to 970 MJ for manufacturing a new tyre.	Primary areas of concern are volatile organic compounds from solvents, bonding agents and rubber compounds during vulcanization. Odour may also be an issue in some areas. The process generates significant wastes. The rubber removed from used tyres before retreading is generally sold as rubber crumbs for other purposes.
Industrial and consumer products	Artificial turf	• Skid resistant; • High impact resistance; • Durable; • Highly resilient; • Easy maintenance; • Independent of irrigation;	• Risk of increased leaching of zinc
	Playgrounds and sports grounds	• Smooth with consistent thickness; • High impact resistance; • Durable; • Will not crack easily; • Available in various colours;	• Risk of increased leaching of zinc
	Applications in rubber modified concrete	• Lower modulus of elasticity, which reduces brittle failure; • Increased energy absorption, making them suitable for use in crash barriers, etc.; • Suitable for low weight-bearing structures; • Can be reprocessed by grinding and mixing again with cement;	• Relatively new product, producers will have to persuade the construction industry of its suitability;
	Road applications	• Increased durability; • Surface resilience; • Reduced maintenance; • Increased resistance to deformation and cracking; • More resistant to cracking at lower temperatures; • Aids in the reduction of road noise; • Substitutes for virgin materials such as styrene-butadiene-styrene • Significant environmental benefits documented with respect to global-warming potential, acidification and cumulative energy demand;	• Very sensitive to changes in conditions during mixing, i.e., requires expert knowledge; • Difficult to apply in wet weather; • Not applicable when ambient or surface temperatures are lower than 13ºC; • Possible occupational health problems due to emissions; • It cannot be reprocessed, unlike traditional asphalt.
	Train and tram rail beds.	• Longer lifespan compared with timber (20 years for rubber beds and 3–4 for wood or asphalt); • Environmentally safe; • More flush with road; • Use chips/shreds as vibration-damping layer beneath subballast;	• More expensive than traditional material; • Relatively new product, producers will have to persuade the industry of its suitability;

	Indoor safety flooring	• Skid resistant; • High impact resistance; • Durable; • Available in various colours; • Easy maintenance;	• More expensive than conventional alternatives; • Colours may be limited; • Limited market;
	Shipping container liners	• Possible use with other packaging problems;	• More expensive than conventional alternatives;
	Conveyor belts	• Possible use as conveyor belt at supermarket checkouts;	• More expensive than conventional alternatives; • Cannot be used where the belt is subject to major stresses, since it may be prone to failure;
	Footwear	• Water resistant; • Long life span; • By varying the thickness of the sole the use of the footwear can be changed;	• Could be more expensive to manufacture than a conventional product;
	Carpet underlay	• Easy to use; • Recyclable; • Conserves natural resources;	• Limited industrial production;
	Roof tiles	• Looks like traditional tile; • Durable (40 to 50 years warranty US and Canadian tiles); • Lighter; • Cheaper long-term cost;	• Limited industrial production;
	Floor tiles	• Resilient; • Skid resistant; • High impact; • Easy maintenance; • Recyclable;	• Limited industrial production;
	Activated carbon (carbon black)	• Preserves virgin material;	• Very expensive process as it needs pyrolysis; • Very energy intensive; • Low-grade activated carbon; • Still at the research stage;
	Livestock mattresses	• Long life span; • Easy to disinfect; • Reusable; • In the long term it is cheaper than alternatives;	• Could be more expensive to manufacture than conventional mattresses; • Market potential unknown;
	TPE thermoplastic elastomers	• Similar properties to typical elastomeric materials;	• Very limited existing sites;
Civil engineering	Landfill engineering	• Lightweight, low-density fill material; • Good load-bearing capacity; • Lower cost compared to gravel; • Does not call for highly qualified labour;	• Potential leaching of metals and hydrocarbons; • The steel cord in the tyre could puncture the lining; • Compressibility of the tyre; • Increased risk of fires;

Civil engineering	Landfill engineering	• Lightweight, low-density fill material; • Good load-bearing capacity; • Lower cost compared to gravel; • Does not call for highly qualified labour;	• Potential leaching of metals and hydrocarbons; • The steel cord in the tyre could puncture the lining; • Compressibility of the tyre; • Increased risk of fires;
	Lightweight fill and soil enforcement	• Reduced unit weight compared with other alternatives; • Flexible, with good load-bearing capacity; • Good drainage;	• Potential leaching of metals and hydrocarbons; • Deformation under vertical load, when proper soil cover thickness is not maintained; • Compaction difficult (need to use more than 10-ton roller, six passes, 300mm lift) ;
	Erosion control	• Low density, which allows free-floating structures to act as wave barriers; • Bales are lightweight and easy to handle; • Durability;	• Tyres should be securely anchored to prevent mobility under flood conditions; • Tyres can trap debris, (need maintenance); • Anchors can shift over time due to wave action, rendering tyre structures insecure; • Water action and tyre buoyancy makes the positioning of any permanent protection below the surface very difficult; • Ultimately, the tyres themselves become waste.
	Noise barriers	• Lightweight, and can therefore be used in geologically-weak areas where traditional materials would prove too heavy; • Free draining and durable;	• Needs monitoring to avoid accumulation of debris; • Visual impact;
	Thermal insulation	• Low thermal conductivity; • Lower overall cost than traditional materials;	• Compressible; • Relatively new product, producers will need to persuade the construction industry of its suitability;
Pyrolysis	Pyrolysis	• Reutilizes the by-products of pyrolysis (oil and gas);	• Limited capacity because of operational problems caused by tyres; • Very limited existing sites; • Sludge originating from the process contains metals and other wastes, which, for the moment, are deposited in abandoned mines thus posing an environmental problem;
Co-processing	Alternative fuel and/or raw material (e.g., cement kilns or steel production)	• High calorific value; • Large volume potential; • Recovery of energy and steel;	• Special monitoring equipment required to control emissions; • Needs a system for supplying the separated waste/tyre fractions; • Increased zinc loading filter dust and/or clinker;
Co-incineration in plants for electric power generation	Alternative fuel for power plants	• Recovery of energy; • Possibility of recovering metals from the ash;	• Measuring equipment required to control emissions; • Increased zinc-loading filter dust and/or bottom ash.

Source: Adapted from the Questor Centre (2005), Hylands and Shulman (2003) and Aliapur (2007).

Table 12
Problems related to environmentally sound means of disposal and ways of preventing and controlling them

Means of disposal	Problems	Prevention and control methods
Retreading	• Generation of rubber residues;	
Ambient/cryogenic grinding	• Noise, dust;	• Exhaust systems; • Combination of ambient and cryogenic recycling for high quality materials; • Work areas designed with sound barriers;
Devulcanization/reclaim	• Liquid effluents; • Air emissions;	• Re-circulation systems for water; • Exhaust and air treatment systems;
Use in industrial and consumer products	• Generation of rubber residues;	
Use in civil engineering	• Leaching; • Air emissions; • Occupational problems; • Fires;	• Alternative non-leachate or impermeable materials used for direct contact with soil; • Personal protection equipment; Limited quantity used;
Pyrolysis	• Air emissions; • Hazardous residues; • Liquid effluents;	• Air and water treatment systems; Technologies for ESM of hazardous wastes;
Co-processing	• Risk of air emissions above legal limits;	• Monitoring and stabilization of critical process parameters, i.e., homogenous raw mix and fuel feed; • Regular dosage and excess oxygen; • Emission control device operating temperature below 200 ºC • Process control optimization, including computer-based automatic control systems; • Modern fuel feed systems. • Minimizing fuel energy by means of preheating and precalcination, where possible; • Preventive measures in unexpected shut down.

Notes to tables 11 and 12:

- 1. These lists are not exhaustive, but illustrate the most important treatment options and applications in use or under development.
- 2. All the applications mentioned above need raw materials obtained from end-of-life tyres, as either chips, shreds or granulates. The size reduction and disposal processes employed require adequate installations to dealwith the environmental and occupational health problems that could otherwise occur. Adequate safety and control equipment should be installed where required.
- 3. 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.
- 4. The standards mentioned below contain detailed information on all applications and operational procedures. It is highly recommended that they be consulted before any decision is taken on environmentally sound means of disposal:

(a) "Standard Practice for use of scrap tyres in civil engineering applications – Designation D- 6270 – 98", (Reapproved, 2004), American Society for Testing Materials (ASTM International);

(b) "Materials produced from end-of-life tyres – Specifications of categories based on their dimension(s) and impurities and methods for determining their dimension(s) and impurities", April 2010, CEN/TS 14243:2010.

113. The most widespread recovery techniques are recycling and energy recovery. There are also techniques for the disposal of tyres not leading to recovery.

114. It is important to keep in mind that the regulations for waste and/or end-of-life tyre management and the economic context will in most cases determine the various means used to manage the flow of incoming tyres.

115. In the current worldwide energy situation, waste pneumatic tyres may be considered to be alternative fuels. They could be used for that purpose, either whole or cut in pieces or shredded. The use of shredded tyres is appropriate in most applications, owing to improved handling and volume reduction. Shred tyres can be easily transported, so the method of transport can be optimized (weight ratios: 0.5t/m^3); the same transport capacity would carry a far smaller quantity of whole tyres (the weight ratio is three times lower at 0.15t/m^3). This has a direct impact on transportation needs and therefore on costs. The production of shredded tyres also minimizes the risk of providing breeding sites for mosquitoes.

116. The recovery capacity of cement kilns can be used to recover energy from end-of-life tyres, which is important because the industry is seeking alternative fuels in the waste market. Increasingly, cement kilns are being technically modified to use shreds of end-of-life tyres as alternative energy.

117. In the same context as tyre recovery in cement kilns, power stations are increasingly ready to use shreds of waste pneumatic tyres as an alternative fuel. Waste pneumatic tyres should be used to generate energy only in installations with adequate emission abatement equipment.

118. The use of materials produced from tyres, such as rubber granulates or powder, is growing and accounts for a large percentage of the management of end-of-life tyres. There is large and increasing market potential for the use of such secondary raw materials. The production processes for these materials normally begin with shredding, followed by grinding to obtain smaller particles. Other components of the tyres are also separated and recovered during the production process, especially the metals.

119. Granulate and rubber powder have a variety of possible applications: as filler in artificial sports grounds (artificial turf), plain rolls; acoustic protection; rubber carpets for cows; children's soft playgrounds; and rubber asphalt. Rubber asphalt for road pavements calls for the consumption of large quantities of rubber powder and gives pavements good characteristics and properties.

120. The carbon content of tyres makes them suitable for use in arc electric furnaces or foundry kilns to replace anthracite. Most of these installations can use shredded tyres. Granulation is not required. Many levels of technology are currently being applied to the recycling of tyre materials, ranging from basic shredding into rough shreds and chips intended for energy recovery or backfilling purposes, to highly sophisticated, fully automated plants.

121. Whereas first-generation recycling facilities have often been criticized for generating dust and noise and a high proportion of waste material, the newest, capital-intensive, fully automated plants using best available technology are able to meet the strictest emission and health regulations and to recover rubber granules, rubber powder and steel. These products are of such uniformity and cleanliness that they can replace virgin rubber and steel in the manufacture of new tyres.

122. Table 13 shows the quantities of ground rubber, steel, fibre and residues obtained from truck and car tyres.

Table 13
Reusable products from scrap tyres

Product	Truck tyres	Car tyres
Ground rubber	70%	70%
Steel	27%	15%
Fibre and scrap	3%	15%

Source: Adapted from Reschner (2006).

1. Retreading

123. Three types of retreading processes (top-capping, re-capping and bead to bead) are described below:

(a) Top-capped tyres are those in which the tread is removed and replaced with a new one;

(b) Re-capped tyres also have their tread removed, however in this case the new tread 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 tread extends from one side to the other, covering all the lower part of the tyre and the sidewalls with a rubber layer.

124. Retreading should be undertaken in compliance with strict conditions established in technical regulations, by certified companies that comply with regulations and laws.

125. In some cases, a criterion for tyre retreading is to control the number of times that a tyre may be retreaded. According to United Nations regulations No. 108 (uniform provisions concerning the approval for the production of retreaded pneumatic tyres for motor vehicles and their trailers) and No. 109 (uniform provisions concerning the approval for the production of retreaded pneumatic tyres for commercial vehicles and their trailers), passenger automobile tyres may be retreaded just once, while truck and aircraft tyres, thanks to their stronger structure, may be retreaded more often (in the case of truck tyres typically up to four times, and for aircraft tyres easily up to 10 times) provided that quality standards are satisfied. In addition, the lifetime of an original tyre casing should be taken into account, and must not exceed seven years.

126. The retreading of motorcycle tyres is prohibited in some countries for safety reasons. To meet safety standards, tyre retreading should be carried out only by qualified companies, and tyres should be certified to guarantee safety and quality standards. It is important therefore that consumers purchase retreaded tyres from companies that follow the rules for retreading systems, and that they have their tyres certified.

127. The environmental impacts of retreading tyres are generally positive. Retreading a tyre consumes considerably less material and energy than are required for a new tyre, with a proportional decrease in other impacts. Various authors have published data in broad terms about the energy and material savings to be gained from retreading. Retreading uses 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, although the actual reduction varies depending on the type of retreading (whether hot, cold or remoulding). The estimates available for tyres indicate that retreading, when carried out with appropriate technology, has significant potential to reduce overall energy and greenhouse emissions, while reducing the quantity of waste tyres produced.[28]

128. Tyre retreading is beneficial to the environment because it minimizes the generation of waste and increases the useful life of tyres, thereby postponing their disposal. From the point of view of waste tyre generation, it is important to note that tyres can be retreaded only a limited number of times. The use of poor quality casings may therefore result, in the long term, in an increase in the overall volume of waste tyres within a country.

129. Retreading avoids the use of raw materials for the production of new tyres, increasing the useful life of tyres and postponing their final disposal as waste. Examples of waste minimization include the use of retreaded tyres on official vehicles and periodic technical inspections that promote the retreadability of used tyres.

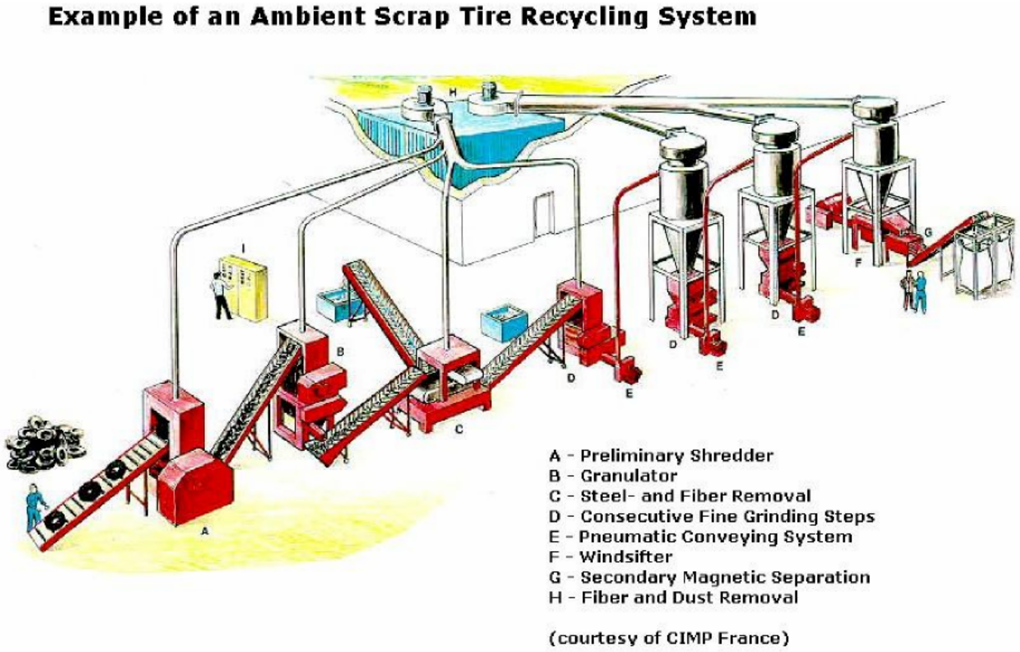
2. Ambient/cryogenic recycling

130. Used whole tyres can be reused in other ways, but most recycling procedures make use of ground tyres because the rubber is then viable in various applications. A tyre may be shredded or ground at a number of grades, depending on the intended end use.

131. Figure V shows the schematic of a typical ambient waste tyre recycling plant, with its various steps and control systems. 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.

28 A National Approach to Waste Tyres (2001).

Figure V
Schematic of an ambient waste tyre processing plant



Source: Reschner (2006).

132. 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, when they are reduced in size to less than 3/8” (10 mm);

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

(d) Successive grinding steps then obtain the appropriate size, usually between 10 and 30 mesh (0.6–2 mm).

133. Ambient recycling can take place in large, fully automated processing plants with capacities currently up to 65,000 tons/input per year and accepting all types of pneumatic tyres (including passenger cars, vans, trucks and earth-moving vehicles). The plants produce rubber granulate and powder of high uniformity and purity in addition to a steel fraction ready for remelting in steel plants. All rubber granulate output can be produced in sizes below 10 mesh (2.0 mm).

134. Ambient recycling generates noise and dust, and energy consumption is intense (120–125 Kwh/ton). To ensure worker 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, in addition to protective headgear should be mandatory. An appropriate site for storing ground rubber should also be provided. The site should be protected from sunlight.

135. These measures will affect the costs associated with operating and maintaining the system. As to worker health and safety, collective protection measures should be adopted first, followed by individual protection.

136. The tyre recycling process is called “cryogenic” because whole tyres or tyre chips are cooled down to a temperature of below -80° 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 fibre liberation, resulting in a cleaner end product.

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

138. The cryogenic process is illustrated in figure VI.

Figure VI
Cryogenic waste tyre recycling

Source: Reschner (2006).

139. The cryogenic process is as follows:

(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 fibre are eliminated;

(e) The material is dried;

(f) The material is classified into defined particle sizes;

(g) Fine mesh rubber powder is obtained.

140. Table 14 shows a comparison between parameters from the ambient recycling system and the cryogenic process.

Table 14
Comparison of ambient recycling and cryogenic recycling

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 reduction per grinding step	Wide particle size distribution (ranging from 10 mm to 0.2 mm) in just one processing step
Liquid nitrogen consumption	N/A	0.5–1 kg liquid nitrogen per kg tyre input

Source: Reschner (2006).

141. Ambient and cryogenic recycling can be combined in such a way that the ambient-produced rubber granulate is further processed into fine powder below 80 mesh (0.2 mm) using a specific

cryogenic technology that ensures high purity, enabling the powder to be used in sophisticated applications, such as rubber compounds for new tyres.

142. Table 15 shows the nomenclature used to classify tyre products as a function of their size.

Table 15
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).

3. Devulcanization and reclaim

143. 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-sulphur (C-S) and/or sulphur-sulphur (S-S) bonds. These confer durability, elasticity and solvent resistance. Reclaimed rubber is used to manufacture products for which the demand and the applications are limited, because it has mechanical properties inferior to those of the original.

144. Devulcanization involves size reduction and cleaving of the chemical bonds, which can be achieved through four processes in which the costs and technologies differ widely: chemical, ultrasound and microwave.[29]

145. The chemical devulcanization process is a batch process in which 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 is then packaged for commercialization.

146. In the ultrasonic 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.

147. The microwave process applies thermal energy swiftly and uniformly to the waste rubber. Any vulcanized rubber used in the microwave process must, however, be sufficiently polar in structure for the microwave energy to be absorbed at the appropriate rate to make devulcanization viable. The only reasonable use for microwave devulcanization is with compounds containing mainly polar rubber, which limits its application. For example, Global Resource Corporation of the United States has developed a technology whereby petroleum-based materials, such as waste pneumatic tyres, are subject to microwaved radiation at specifically selected frequencies for a time sufficient partially to decompose the materials into a combination of oils and consumable gas.[30]

148. Available 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 occur.

149. A report published by Calrecovery Inc. in 2004 lists approximately 50 organic compounds, including benzene, toluene and heptanes as types of emissions from the vulcanization area of a tyre

29 Calrecovery Inc. (2004).

30 Gert-Jan van der Have (2008).

retreading operation and from a tyre retreading extrusion operation. There is also a possibility that hydrogen sulphide and sulphur dioxide will be released through the oxidation of hydrogen sulphide. Consequently, the process will call for filters to control emissions and gas scrubbers to remove sulphur dioxide. Liquid effluents coming from the scrubber should be dealt with appropriately before they are launched into water bodies.

150. Table 16 includes information about the costs and production capacities of devulcanized rubber.

Table 16
Estimated costs of producing devulcanized rubber

Item	Chemical process	Ultrasonic process
Capacity (kg/h)	34	34
Capital cost ($103)	166	163
Operation and maintenance costs ($103)	172	136

Source: Calrecovery Inc., "California Integrated Waste Management Board" (2004).

4. Industrial and consumer products

151. The industrial and consumer markets for rubber powder and granulate have increased dramatically in recent years. A wide and growing range of applications is in use, including artificial turf, playground and sports ground surfaces, asphalt and bitumen modification, indoor safety flooring, shipping container liners, conveyor belts, car mats, footwear, carpet underlay, roof tiles, flooring, activated carbon, livestock mattresses and thermoplastic elastomers. The most important applications are described in brief below.

(a) Artificial turf

152. Rubber granulate is used in artificial turf in two ways: as a filler in artificial sports fields and in the manufacturing of elastic pads, either constructed on site or prefabricated. A standard artificial turf pitch contains 100–130 tons of rubber granulate infill material. If an elastic pad is added, another 60–80 tons of rubber granulate is consumed.

153. When used as infill material, rubber granulate replaces virgin materials such as ethylene propylene diene monomer and thermoplastic elastomers. It is used in turf for such contact sports as soccer, American football and hockey. Global annual growth rates have been above 25 per cent since 2001 and are expected to continue to rise at double-digit rates.

154. Artificial soccer turf is highly recommended by the Fédération Internationale de Football Association owing to its high performance with regard to ball behaviour, maintenance costs, lack of water dependency and positive social profile (since it can be produced at a modest price).

(b) Playgrounds and sports grounds

155. The elastic and noise-reducing properties of rubber granulate are evident when building playgrounds for children, athletic tracks and other sport surfaces. The rubber granulate is mixed with polyurethane and the top layer is often dyed. The European Union has issued compulsory standards (EN 1177) for the surface elasticity of public playgrounds.

(c) Applications in rubber-modified concrete

156. Rubber-modified concrete improves the absorption of impact energy and reduces cracks. Work in Brazil has concentrated on the use of rubber-modified concrete in the construction of highway barriers and other products, using a mixture of conventional concrete, rubber aggregate and fibreglass.

157. Other applications for the manufacture of industrial and consumer products are discussed in works by Hylands and Shulman (see footnote 29) and by the Questor Centre (2005). They include:

(a) Sports surfaces;

(b) Indoor safety flooring;

(c) Playground surfaces;

(d) Shipping container liners;

(e) Conveyor belts;

(f) Car mats;

(g) Footwear;

(h) Carpet underlay;

(i) Roof tiles;

(j) Flooring;

(k) Activated carbon (carbon black);

(l) Livestock mattresses;

(m) Thermoplastic elastomers.

(d) Road applications

158. 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: the wet process and the dry process.[31]

159. In the dry process, rubber powder is added directly into asphalt, causing a reaction between the rubber and the bitumen. This process is suitable for hot-mix paving projects and surface treatments.

160. In the traditional wet process, rubber powder is used as a bitumen modifier. Rubber powder is blended with bitumen before the binder is added to the aggregate. The ideal particle size for the wet process ranges from 0.6 mm to 0.15 mm. Material should be heated to between 149° C and 190° C before compaction. This makes the process more expensive than using conventional asphalt, and emissions of toxic substances are likely during both production and application. The wet process has been shown to have better physical properties than the dry.

161. Rubber asphalt is still not widely accepted, and its environmental impacts have not been fully analysed. It also requires higher initial investment. In Europe, only 1 per cent of rubber granulates is used for highway surfacing contributing to the recycling of a little over one quarter of 1 per cent of the waste tyres generated in Europe. The United States Congress began to require the use of rubber asphalt for federally funded projects in 1991, but environmental and public health concerns resulted in the withdrawal of this requirement five years later.[32] While several states in the United States use rubber asphalt in their highway projects, research is continuing into its impacts on the environment and health of workers.[33] Today, rubber asphalt applications account for the disposal of 2 per cent of tyre wastes.[34]

162. A new generation of bitumen modifiers based on recycled rubber powder in combination with a virgin material (a semicrystalline polyoctenamer) has entered the market in recent years. It replaces traditional virgin bitumen modifiers such as styrene-butadiene-styrene and is sold at the same price level. The advantage of these new modifiers is that problems, such as emissions of toxic substances during production and application and other environmental impacts, unsuitability for use with existing road construction equipment, high temperature on compaction, slippery surface and emission problems during recycling of asphalt, can be avoided.[35]

163. In the United States, the National Institute for Occupational Safety and Health report referred to above concluded that rubberized asphalt does not produce fumes in excess of the exposure limits established by safety and health regulatory agencies.[36] While the composition of the emissions and fumes may vary, they proceed from the base asphalt, not from the rubber. In all cases, emissions and fumes are within the limits set by every United States permitting and regulatory authority.

164. A recent, peer-reviewed, life-cycle-assessment study has also shown that a scenario in which tyres are recycled and used for new generation bitumen modification, compared with a scenario in which the tyres are co-incinerated in cement kilns, yields significant environmental benefits in impact

31 Caltrans (January 2003).

32 Intermodal Surface Transportation Efficiency (1995).

33 United States Department of Transportation, Federal Highway Administration, Crumb Rubber Modifier.

34 Sheerin, John (2004).

35 FABES (2006).

36 National Institute for Occupational Safety and Health (2001).

categories such as potential for global warming, acidification and cumulative energy demand (DTC & IFEU 2008).[37]

165. The use of rubber in asphalt is extremely expensive and does not always comply with standards developed by individual states in the United States. Some states have not yet developed standards for the use of tyre rubber in asphalt. In those states where rubberized asphalt is routinely used, the percentage of tyres used in the application ranges from 10 to 85 per cent. The use of waste tyres in road-paving applications is cost-effective and beneficial; the market for such use is promising. Tyre rubber represents an excellent additive to asphalt material and serves to reduce cracking and the hardening through age of asphalt material, which prolongs the useful life of pavements.

5. Civil engineering

166. Civil engineering applications of waste tyres are discussed in the American Society for Testing and Materials (ASTM) standard 6270/1998B and also in European Committee for Standardization Technical Specification (CEN/TS) 14243:2010.

167. Civil engineering applications of waste tyres encompass a wide range of uses, often replacing construction materials such as soil or sand. They can also be used as aggregate in construction projects like road bases and embankments, septic system drainage media, fill material and landfill applications.

168. Policy guidelines, standard practices and leachability determinants for civil engineering applications have been developed and are in use in some countries. Policy guidelines developed by the Tennessee state government in the United States describe civil engineering applications that are appropriate for used tyres.

169. ASTM developed a standard for the use of scrap tyres in civil engineering applications (standard ASTM 6270/1998B), which provides guidance for testing the physical properties, design considerations, construction practices and leachate generation potential of processed or whole scrap tyres, in lieu of conventional civil engineering materials, such as stone, gravel, soil, sand, lightweight aggregate, or other fill materials.

170. The Environment Agency of England and Wales developed leachability determinants for materials intended for engineering applications such as noise barriers, landfill reinforcement, etc., (see appendix II, part B, of the present guidelines) with limit values for chemical properties of the materials used.

(a) Landfill engineering

171. Applications for waste tyres in landfill engineering should be temporary and should never be part of permanent functional units, which would represent a high risk for constituting a hidden landfill of waste and pose an unacceptable risk were a fire to occur in the landfill site. Temporary applications may include:

(a) Leachate collection;

(b) Protective layer for geotextiles;

(c) Drainage layer in landfill cover;

(d) Fill for landfill gas drainage systems;

(e) Daily cover for landfills;

(f) Temporary roads;

(g) Tyre bales in landfill haul roads.

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

(b) Lightweight fill and soil enforcement

173. Tyres are used as lightweight fill in various engineering projects, such as behind retaining structures and in embankments, as backfill to integral bridge abutments and slope repair and stabilization, and for slope stabilization, partially replacing quarried aggregate or gravel and aggregate

37 DTC and IFEU (2008).

filled gabions, depending on the project. These applications use whole tyres, cut tyres (up to 300 mm), tyre shreds (50 mm to 300 mm), and tyre chips (10 mm to 50 mm).

(c) Erosion control

174. Tyres' durability and stability are ideal when they are used in projects for erosion control. Tyres have been used both for coastal and fluvial erosion control projects to absorb the energy created by moving water, in either tidal or fluvial flows, in addition to rainwater. Waste tyres have also been used in the environmental reclamation of eroded gullies and small canyons through filling, in addition to in the construction of erosion control barriers, thus becoming part of the eroded landscape, to be subsequently replanted with vegetation.

(d) Noise barriers

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

(e) Thermal insulation

176. Tie cuts, shreds and chips are used as 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, tyres 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 pipes. Highway edge drains built with tyres have been shown to resist freezing during very cold winters.

177. Using shredded waste tyres as a lightweight fill material for road construction has proved to be another beneficial use of end-of-life tyres, e.g., in logging roads through areas with weak soils.[38] Their lightweight nature is a considerable advantage for placing in soft ground, as it imposes much less load on the underlying soil than natural aggregate.[39]

6. Pyrolysis

178. Pyrolysis is a 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.

179. Some pyrolysis technologies have produced oil with a low energy content (when compared with diesel oil), a synthetic gas, known as "syngas" (with low heat properties), carbon black, char and steel. Modern techniques that carry out thermal degradation of plastics in tyres in a rarefied atmosphere will, however, produce oils that are directly comparable in viscosity and calorific values with diesel and gasoline type fuels.

180. The syngas obtained from these techniques can have a calorific value the equivalent of propane and has excellent heat properties. The steel produced can be high-quality tensile steel, which can be used to remanufacture new tyre wire.

181. Pyrolysis char produced by some techniques in this process has had low commercial value, as it consists of a mixture of the carbon blacks used in the manufacture of tyres. The resulting product therefore lacks the same quality as those of the original carbon blacks used in the manufacture of tyres. However, modern techniques may produce a char comparable to virgin carbon black.

182. In some cases it is necessary to upgrade the pyrolyisis char through particle size reduction for the purpose of developing new products. Resonance disintegration produces ultrafine carbon products from pyrolysis char. During resonance disintegration, char granules experience multiple high-energy shockwaves, resulting in the immediate production of carbon having an average primary particle diameter of 38 nanometres in aggregates and agglomerates ranging in size from 100 nanometres to 10 microns.[40]

183. Another possibility is using pyrolysis char as activated carbon. Carbon char is normally activated by applying steam which is a normal by-product of the process.

184. Like with any other process, there might be risks associated to the conduction of a poor pyrolysis process. Material such as steel recovered from pyrolysis may be contaminated with carbon

38 United States Environmental Protection Agency, "Wastes – Resource Conservation – Common Wastes and Materials – Scrap Tires".

39 Reid, J. M. and M. G. Winter (2004).

40 Karpetsky, Timothy (2001).

for which metal re-processors markets are not available. Usually, the recovered steel is also in the form of a tangled, high-volume mass, which renders it difficult and costly to handle and transport.

185. In the United States, pyrolysis has not yet been proven to be an economically viable operation. It has been attempted over 30 times and has always failed as a full-scale operation; investors have lost millions and states have had to incur costly clean-up activities. The pyrolysis process is capable of creating hazardous waste pyrolytic oils that need to be managed accordingly.

186. The pyrolysis process is normally via thermal decomposition and it is capable to recover materials such as diesel and gasoline equivalent oils, propane equivalent gas, steel and refined carbon black that can be reused to manufacture new products.

7. Co-processing

187. The term "co-processing" refers to the use of waste materials in industrial processes, such as cement and lime or steel production. It may involve energy recovery as well as the recovery of materials from waste. .[41] In this section, only co-processing in cement kilns is adressed. Further detailed information on co-processing in cement kilns is provided in the technical guidelines on environmentally sound co-processing in cement kilns.

188. Studies on the use of tyres in cement kilns have not yielded consistent results for the impacts of co-processing on detectable levels of dangerous substances. Accordingly, the convenience of authorizing the co-processing of tyres in cement kilns needs to be considered on a case-by-case basis, as its safety depends on good operating practice and on the particular characteristics of the tyres and kiln used.

189. In Europe, the cement industry recovers a substantial amount of waste to replace conventional fossil fuels and/or raw materials. Following appropriate treatment, individual waste fractions can meet the requirements for environmentally compatible reuse in cement plants.

190. Tyres are now an established supplementary fuel in cement kilns, and their use in this application allows energy to be recovered from the waste tyre and replaces the use of fossil fuels. The relevant national authorities regulate this process and consider it to be an acceptable option, provided that specified process control and admission criteria are adhered to and provided that the requirements of the relevant legislation are met (in the European Union these requirements are laid down in the 2000/76/EC Waste Incineration Directive).

191. Co-processing is a means of recovering energy and material from refuse, and can be used partially to replace fuel and raw material in the production of cement clinker. Basically, the characteristics of the clinker burning process itself permit environmentally beneficial waste-to-energy and material recycling applications. The essential process characteristics for the use of waste can be summarized as follows:

(a) Maximum temperatures of approximately 2,000° C (main firing system, flame temperature) in rotary kilns;

(b) Gas retention times of about eight seconds at temperatures above 1,200° C in rotary kilns;

(c) Material temperatures of about 1,450° C in the sintering zone of the rotary kiln;

(d) Oxidizing gas atmosphere in the rotary kiln;

(e) Gas retention time in the secondary firing system of more than two seconds at temperatures above 850° C; in precalciner, the retention times are correspondingly longer and temperatures are higher;

(f) Solids temperatures of 850° C in the secondary firing system and/or the calciner;

(g) Uniform burnout conditions for load fluctuations due to the high temperatures at sufficiently long retention times;

(h) Destruction of organic pollutants due to the high temperatures at sufficiently long retention times;

(i) Adsorption of gaseous components such as fluoridric acid, hydrochloric acid and sulphur dioxide on alkaline reactants;

41 Holcim, GTZ (2006).

(j) High retention capacity for particle-bound heavy metals;

(k) Short retention times of exhaust gases in the temperature range, which inhibits de-novo-synthesis of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans;

(l) Complete use of mineral parts of fuel and waste as clinker components, and therefore simultaneous material recycling (e.g., also as a component of the raw material) and energy recovery, regardless of the calorific value;

(m) Product-specific wastes are not generated, as a result of a complete material use into the clinker matrix; however, some cement plants in Europe dispose of bypass dust through chemical-mineralogical incorporation of non-volatile heavy metals into the clinker matrix.

(a) Quality requirements

192. A consistent quality of waste is essential. To guarantee the characteristics of the waste fuel, a quality assurance system is needed. As a general rule, wastes accepted as fuels and/or raw materials must give calorific and/or material added value to the cement kiln. The high heat value (25~35 MJ/kg) of tyres as compared to coal (18.6–27.9 MJ/kg) is therefore quite attractive.

193. Waste materials used as raw materials and/or as fuels in cement kilns have to reach different quality standards because the fuel ashes are fully captured in the clinker, and to minimize negative effects on clinker compositions and air emissions.

(b) Emissions

194. Part II of Annex C to the Stockholm Convention lists cement kilns firing hazardous wastes as an industrial source with potential for the formation and liberation of comparatively high amounts of polychlorinated dibenzo-p-dioxins, dibenzofurans, hexachlorobenzene and polychlorinated biphenyls into the environment.

195. The revised draft guidelines on best available techniques and provisional guidance on best environmental practices relevant to Article 5 of and Annex C to the Stockholm Convention, adopted at the Conference of the Parties to the Convention in 2007, pertain to this issue and provide valuable information. The 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/Nm^3 (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.

196. Findings from the Foundation for Scientific and Industrial Research, based on 1,700 polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran measurements from 1990 to 2004, demonstrate, however, that most cement kilns can meet an emission level of 0.1 ng TEQ/Nm^3. The data represent emissions from cement kilns in developed and developing countries using a wide range of fuel sources, including hazardous wastes and tyre-derived fuel.[42] The Canadian Council of Ministers of the Environment drew a similar conclusion, stating "available test data from the cement sector indicate releases of dioxins and furans from cement kilns are below 80 pg/m^3, with one exception. To date, 80 pg/m^3 is the lowest emission limit established by a Canada-wide Standard based on available technology and feasibility".[43]

197. A set of data on different emission levels when wastes are used as raw materials and/or fuels (including the use of waste pneumatic tyres as fuel) along with best available techniques for emissions reduction, are available in the reference document on the best available techniques in cement, lime and magnesium oxide manufacturing.[44]

198. The data from a number of research studies on emissions during co-processing of tyres in cement kilns are controversial, however. In terms of emissions formation, proponents of tyre-derived

42 Foundation for Scientific and Industrial Research (2006).

43 Canadian Council of Ministers of the Environment (2004).

44 European Comission (May 2010).

fuel argue that, by using process optimization measures along with improved and optimized kiln systems and a smooth and stable kiln process, the co-processing of tyres and other hazardous wastes is no different than conventional coal combustion. It is also essential to apply modern, well-designed and well-maintained emission reduction techniques.

(c) Monitoring and measuring techniques for emissions reduction

199. Process control and monitoring is essential to keep emissions low. To control emissions, some additional environmental equipment may be installed. Special control and process measures are needed to maintain environmental, safety and quality standards. Depending on the types of waste used and their characteristics, the feed points into the kiln have to be taken into consideration, as the way in which the fuels are fed into the kiln can affect emissions.

200. The main environmental issues associated with cement production are emissions to air and energy use. Emissions to air, e.g., emissions of dust, nitrogen oxide, sulphur oxide, carbon monoxide, total organic carbon, polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, and metals occur in the manufacture of cement.

201. If monitoring indicates that statutory emissions are being exceeded during a test burn, the burn should be stopped until the cause of the instability has been established and rectified. Tyre burning should be allowed on a permanent basis only if the data from the test burn show that co-processing will not pose additional risks to the environment. Investigations conducted in the European cement sector have concluded that it is rarely a significant source of PCDD/PCDF emissions because:

(a) Most cement kilns in the European Union can meet an emission level of 0.1 ng I-TEQ/Nm3 if primary measures are applied;

(b) Use of waste as fuel and as raw materials fed into the main burner, kiln inlet or the precalciner do not seem to influence or change the emissions of persistent organic pollutants (POPs). (88, SINTEF, 2006)].

202. Measures can be taken to minimize emissions of polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans and to comply with an emission level of 0.1 ng polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans I-TEQ/Nm^3. These include a smooth and stable kiln process, operating close to the process parameter set points, which is beneficial for all kiln emissions and for energy use. This can be obtained by applying:

(a) Process control optimization, including a computer-based automatic control system;

(b) Use of modern fuel feed systems;

(c) Minimizing fuel energy use by means of preheating and precalcination, taking account of the existing kiln system configuration;

(d) Careful selection and control of substances entering the kiln: selection and use of homogeneous raw materials and fuels with a low content of sulphur, nitrogen, chlorine, metals and volatile organic compounds, if practicable.

203. To minimize the possibility of polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran reformation, the following primary measures are considered to be the most important:

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

(b) Limiting residence time of flue gases and oxygen content in zones where the temperatures range between 300° C and 450° C;

(c) Limitation or avoidance of waste used as raw material feed as part of the raw material mix, if it includes organic materials;

(d) Not using waste fuel feeding during start-up and shutdown;

(e) Monitoring and stabilization of critical process parameters, i.e., homogenous raw mix and fuel feed, regular dosage and excess oxygen.[45]

204. Further detailed information on best available techniques for emissions reduction, e.g., for nitrogen oxide, sulphur oxide, carbon monoxide, total organic carbon, polychlorinated dibenzo-p-

45 World Business Council on Sustainable Development/Foundation for Scientific and Industrial Research, “Formation and Release of POP´s in the Cement Industry” (January 2006).

dioxins and polychlorinated dibenzofurans and metals, can be found in the reference document on the best available techniques in the cement industry.[46] This solution has however been questioned, for two basic reasons:

(a) 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 tyres can be reused or material recycled, these options are preferable but should always be assessed using a life-cycle methodology, taking into account alternative waste treatment routes and the substitution of natural resources;

(b) Concern over potential emissions during the burning process.

205. With regard to the European Union, the waste incineration directive (2000/76/EC) established lower emission limits from 2008, leading to the deactivation of cement kilns that failed to reach the low emission limits. Cement kilns using the wet process were particularly affected by these more stringent limits. These kilns process around 20 per cent of the scrap tyres used in the cement industry.

206. A factor that is beginning to weigh against the use of traditional fossil fuels such as pet coke as a fuel is related to carbon dioxide emissions. Currently, the burning of fossil fuels accounts for about 40 per cent of emissions from the cement industry. By 2020, projections indicate that demand for cement will rise by 180 per cent relative to 1990 levels. The cement industry, as part of the Cement Sustainability Initiative, aims to maintain emissions at 1990 levels, this increase in demand notwithstanding. This means a reduction of about 40 per cent in carbon dioxide emissions.[47]

8. Co-incineration in plants for electric power generation

207. According to Menezes,[48] incineration is a thermal oxidation process at high temperatures, ranging from 800º C to 1,300º C, used to eliminate organic wastes and to reduce volume and toxicity. Regardless of the objectives for which the burning is conducted, emission control should be strictly enforced, as required by legislation.

208. It is essential that variables such as combustion temperature, residence time, turbulence (indicating the level of mixture as 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.

209. Plants incinerating elastomers, such as tyres or other material, should use state-of-the-art technology to avoid a broad range of emissions caused by 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, and therefore require treatment. Dioxins, furans and polycyclic aromatic hydrocarbons are all by-products of the combustion process, and they require special controls because of the serious harm to human health and the environment that they can cause. Numerous potentially harmful materials can be produced from the combustion of fuels such as coal and oil, in addition to tyres, meaning that the combustion process must take place subject to appropriate combustion conditions and emission controls in order to meet all applicable regulations.

210. For example, incineration is a technology that requires substantial capital investment and faces strong public opposition. Several plants have experienced operational problems that have hindered the reliable supply of electricity. Combustion is capital-intensive. Substitution of tyre-derived fuel for a portion of other solid fuels in existing combustion units generally requires limited investment in appropriate metering equipment to control the rate of tyre-derived-fuel addition. Very few systems are dedicated solely to the combustion of waste tyres, and these are capital-intensive when it comes to power generation, primarily because of their relatively small economies of scale. Some of these plants have encountered economic viability issues, as have systems powered by wood and other renewable energy sources.

211. A number of incinerators, including at plants such as those of Gummi-Mayer (Germany), Sita-Elm Energy (United Kingdom) and Modesto tyres (California) have been closed as a result of these problems. Among those that continue to operate are Exeter (United States), Marangoni (Italy) and Ebara (Japan).

46 European Commission (May 2010).

47 Climate Change, Final Report 8, Battelle Institute/World Business Council for Sustainable Development (2002), p. 24.

48 Menezes (2006).

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Appendix I

Public health literature

Dengue fever is transmitted by mosquitoes breeding in containers that collect rainwater, particularly used tyres.[49] A single tyre can serve as a breeding site for thousands of mosquitoes in just one summer.[50] The Centers for Disease Control and Prevention in the United States recognize 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 programmes are costly and minimize the problem rather than solving it.

One example of this is the species *Aedes albopictus* (also known as the Asian tiger mosquito or the forest day mosquito). This species was accidentally transported from Japan to the western hemisphere in the mid-1980s in shipments of used tyres.[51] Since then, the species has established itself in various states in the United States and in other countries in the Americas, including Argentina, Brazil, Cuba, Dominican Republic, Guatemala and Mexico.[52] It therefore appears clear that the spread of the species benefited from the movement of used tyres between states and countries.

The risks associated with the transportation of used and waste tyres are well known, and specialists and environmental authorities in Canada, the United Kingdom and the United States have drawn attention to them. A public health official in the United Kingdom, referring to the dissemination of *Aedes albopictus* in the United States, 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."[53]

A Japanese study in 2002 demonstrated that tyres transported for final disposal operations (in this case, in 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*."[54]

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 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."[55]

The numbers associated with the dengue epidemic are significant: some 50 million people worldwide are infected every year by the disease, with 500,000 hospitalizations and 12,000 deaths.[56] The World Health Organization recognized that dengue was "the most important emerging tropical viral disease" and "a major international public health concern".[57] Its symptoms range from high fever, severe headaches and muscular pain to haemorrhaging, frequently followed by swelling of the liver

49 World Health Organization, "Dengue and Dengue Hemorrhagic Fever (2002)" ("WHO Dengue Fact Sheet").

50 Ohio Department of Natural Resources (1986).

51 Yamaguchi, E. (2000).

52 Borges, Sonia Marta dos Anjos Alves (2001).

53 "*Biting Back*", Environmental Health Practitioner (2004).

54 Kobayashi, M. and others (2002).

55 Chester, G. Moore and Carl J. Mitchell (1997).

56 Texeira, Maria da Glória (2005).

57 World Health Organization (1999).

and poor circulation.[58] Dengue hemorrhagic fever has a death rate of from 5 per cent to 15 per cent when left untreated.[59] Dengue hemorrhagic 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 World Health Organization, has now reached levels of an explosive epidemic.[60] The current dengue epidemic in Brazil worsened between 1994 and 2002, reaching a peak of 794,000 cases in 2002. Unlike previous localized waves of the disease, the current epidemic spread throughout the country.[61] Cases of hemorrhagic dengue increased 45 times from 2000 until 2002,[62] reaching a peak mortality rate of 4.3 per cent, almost eight times as high as the rate in South-East Asia.[63] Brazil accounted for 70 per cent of reported cases in the Americas from 1998 to 2002.[64] Today, three of the four serotypes of dengue co-circulate in 22 of the 27 states in Brazil,[65] which is disturbing as 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 public awareness campaign in Brazil, 280,511 cases of dengue and 61 deaths were reported from January to October 2006.

Even fumigation is not fully efficient in eliminating 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 sufficiently to reach the mosquitoes,[66] given that they tend to concentrate at the bottom of the pile, where fumigation does not reach them in sufficiently high concentrations. It is therefore not uncommon for them to become resistant to insecticides. According to Solari (2002),[67] 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.”

The disposal of used tyres therefore constitutes a risk factor for the spread of mosquito vectors, and is considered a problem from a public health perspective, especially in tropical countries. This is compounded by the fact that used tyres harbour rodents.

Another risk to public health is the open uncontrolled burning of tyres, which generates emissions of chemical compounds detrimental to human health, such as carbon monoxide, sulphur oxides, nitrogen oxides, polynuclear aromatic hydrocarbons and persistent organic pollutants, e.g., polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans, hexaclorobenzene and polychlorinated biphenyls. The reduction or elimination of non-intentional emissions of such substances is regulated by Article 5 of and Annex C to the Stockholm Convention, although this is not the case if incineration occurs under well-controlled conditions, such as co-incineration in cement kilns.

58 WHO Dengue Fact Sheet.

59 Donald Kennedy and Marjorie Lucks (1999).

60 WHO Dengue Fact Sheet.

61 Siqueira, João Bosco and others (2005).

62 Ibid.

63 Figueiredo, Luiz Tadeu Moraes (1985–2004) (2004).

64 Siqueira, João Bosco and others (2005).

65 Ibid.

66 University of Rhode Island, Office of Mosquito Abatement Coordination, Mosquitoes, Disease and Scrap tyres.

67 Solari, Alfredo. BID América.

Appendix II

Leachate literature

Part A: Summary of reviewed field trials on tyre leachate

Table 1, below, presents a summary of reviewed field trials on tyre leachate.

Table 1: 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.[68]
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 SO4 not increased at site. Fe and Mn increased at site. Negligible level of organics at site.
Riaz[69]	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.

Source: 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.

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.

68 O'Shaughnessy V.O., Garga V.K. (2000).

69 Riaz A.K., Ahmed S. (2001).

As presented in Section I.D.2 (b) the various factors that may affect the rate of leaching and/or the concentration of tyre leachate compounds in soil, surface water and groundwater are described below:[70]

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

(b) **Amount of exposed steel:** if steel is exposed (in the case of tyre chips and shreds), it is likely 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 faster under acidic conditions, while leaching of organic compounds is likely to be faster 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;

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

In a study by Sheehan, P.J. and others (2006),[71] toxicity testing, toxicity identification evaluation and groundwater modelling were used to determine the circumstances under which tyre 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 tyre shred leachates. The results, however, were different for the leachates collected from tyre shreds installed above the water table and below it. The study concludes that, for settings with lower dissolved oxygen concentrations or lower pH, results of groundwater modelling indicate that a greater buffer distance (>11 m) was needed to dilute the leachate to non-toxic levels under various soil and groundwater conditions solely through advection and dispersion processes.

Table 2 describes studies on the use of tyre granulate in artificial sports grounds that reviewed the impacts on the environment of leachate from these granulates.

Table 2
Studies on use of tyre granulate in artificial sports grounds

Author	Conclusion
Källqvist (2005)	• Risk assessment shows that the concentration of zinc poses a significant local risk of environmental effects in surface water which receives run-off from artificial turf pitches. In addition, it is predicted that concentrations of alkylphenols and octylphenol in particular exceed the limits for environmental effects in the scenario which was used (dilution of run-off by a factor of ten in a recipient). The leaching of chemicals from the materials in the artificial turf system is expected to decrease slowly, so that environmental effects could occur over many years. The total quantities of pollution components which are leached out into water from a normal artificial turf pitch are, however, relatively small, so that only local effects can be anticipated.

70 MWH (July 2004).

71 Sheehan, P.J. and others (2006).

Author	Conclusion
Aliapur et al. (2007)	• Physicochemical results of the percolates show for potentially polluting substances a kinetic independent of the type of granulates used, in both in-situ and in-lab tests. Analytically detectable trace substances or compounds are dissolved from the surface and from the polymer matrix of the granules in a concentration that falls over time; • According to current research, after a year's experimentation, the results for the 42 physicochemical parameters identified and from the ecotoxicological tests show that water passing through artificial turf using as filling either virgin elastomers granulated or granulates from used tyres, is not likely to affect water resources in the short and medium terms.
Intron et al. (2007)	• Leaching of heavy metals and organic chemicals such as phthalates and polycyclic aromatic hydrocarbons from recycled car tyres as infill in artificial turf systems is well within the limit values set in the Netherlands for soil and surface water quality. Leaching of zinc is an exception but is not expected to exceed limit values within 10 years.
Müller, E. (2007)	• Dissolved organic carbon and organic nitrogen decrease very rapidly initially, subsequently slowing to a minimum in a time-dependent, substance-specific manner both in the lysimeter trials and in 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; • The very low polycyclic aromatic hydrocarbon 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.
Verschoor (2007)	• The estimated zinc load of 800 mg/m2/year will result in exceedance of the critical load stated in the Building Materials Decree (2100 mg/m2/100 year) within 3 years. One infill with a lifetime of 10 years will exceed the critical load by a factor of 4. Exceeding critical loads implies potential risks to soil, surface water or groundwater. This is confirmed by the exposure assessment addressing the various 'receiving' compartments.
Zhang (2008)	• Rubber granules often, especially in newer synthetic turf fields, contained PAHs at levels above health-based soil standards. PAH levels generally appear to decline as a field ages. However, the decay trend may be complicated by adding new rubber granules to compensate for the loss of the material. • PAHs contained in rubber granules had low bioaccessibility (i.e., hardly dissolved) in synthetic digestive fluids including saliva, gastric fluid, and intestinal fluid. • The zinc contents were found to far exceed the soil limit. • Lead contents were low (53 p.p.m.) in all the samples in reference to soil standards. However, the lead in the rubber granules was highly bioaccessible in the synthetic gastric fluid. The analysis of one artificial grass fibre sample showed a slightly worrisome chromium content (3.93 p.p.m.) and high bio-accessible fractions of lead in both the synthetic gastric and intestinal fluids.
Intron 2008	• The impact of weathering of the rubber crumb for the technical lifetime of an artificial turf field (10–15 years) does not cause the leaching of zinc from the rubber crumb made from recycled car tyres such as to exceed the threshold values for dissolved zinc in surface water or the derived threshold value from the Decree on Soil Quality for the emission of zinc into the soil.

Part B: Leachability determinants for the use of materials intended for engineering purposes

Table 3, below, presents leachability determinants for the use of materials intended for engineering purposes (applicable in the United Kingdom).

Table 3
Leachability determinants for the use of materials intended for engineering purposes (applicable in the United Kingdom)

Application	Chemical property	Limiting values (µg / l, unless stated)*
- Landfill engineering - Lightweight fill and soil - Reinforcement - Bridge abutments - Drainage applications - In-ground barriers - Noise barriers - Thermal insulation - Tyre products and surfacing	pH	5.5–9.5
	Conductivity	1000 µs/cm
	Carbon Organic Dissolved	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
	Nickel	50
	Zinc	500
	Cyanide (free)	50
	Sulphate (SO_4)	150 mg/l
	Sulphide	150
	Sulphur (free)	150
	Phenol	0.5
	Iron	100
	Chloride	200 mg/l
	Polycyclic aromatic hydrocarbons	0.2
- Erosion control (fluvial & - Artificial reefs	As above (if necessary)	As above (if necessary)

* Limiting values relate to the acceptable concentrations of materials into unlined landfill sites, based on the Environment Agency of the England and Wales own internal guidance. (Environmental Agency – www.environment-agency.gov.uk)

Notes

Limiting values for chemical properties of materials used in engineering applications depend 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 the acceptability of contaminated materials for unlined landfill sites.

The leachable concentrations 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 cause no risks to human health or the environment. This must, however, be agreed upon with the regulator before any work takes place, and it is subject to the current waste management licensing scheme.

Pollution of controlled waters falls under the control of the United Kingdom environmental regulators. Further licensing may, however, be required from Department of Environment, Food and Rural Affairs for the discharge of waste materials into 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 to ensure that the material does not cause harm to groundwater, surface water or marine waters. There are concerns about the potential impact on drinking water supplies.

Appendix III

Incidents of fires resulting from tyres that are documented in the literature

The table presents fire incidents resulting from tyres and negative impacts related to them.

Location	Year	Duration	Approx. No. of tyres	Incident management	Adverse Environmental effects	Cause
Rochdale, United Kingdom	1972 April 1975 July 1975	1 day 30 days 10 days	9,000	None reported	Water supply reservoir still closed	Arson suspected
Rhinehart, Winchester, Virginia, United States	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, United Kingdom	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, United Kingdom	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[72]	1700 people evacuated[73], long term monitoring ongoing	700,000 litres run-off of oil into soil. Creek water contaminated (PAHs)	Arson suspected
Saint Amable, Quebec, Canada 7	May 90	6 days[74]	3.5 million[75]	150 people evacuated, 12 million Canadian dollars spent for site decontamination and restoration.[76]	Possible contamination of soil and water by oil released from the burning tyres.	Arson a potential cause
York, United Kingdom	1991	No data available	> 1,000	None reported	Low levels of phenols entered into local stream.	No data available
Cornwall, United Kingdom	1992	1 day	No data available	None reported	Phenol and PAHs detected in runoff water.	Arson suspected
Washington, Pennsylvania, United States	Feb 97	14 days	1.7 million	Evacuation of 500 residents and closing of two schools	None reported	Arson suspected
Gila River Reservation, Arizona , United States	Aug 97	7 days	3 million shredded	Monitoring for ground contamination	None reported	Arson suspected
Cheshire, United Kingdom	1999	Not clear	500	None reported	Run off oil contaminating site	Arson suspected

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

72 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.

73 Ibid.

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

75 Ibid.

76 Ibid.