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Small Intersessional Working Group on the
technical guidelines for the environmentally sound management of used and waste pneumatic tyres
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Item 3 of the provisional agenda*

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

The annex to the present note sets out the draft updated draft updated Technical guidelines for the environmentally sound management of used and waste pneumatic tyres which was prepared by the Secretariat, taking into account comments on the version of the draft guidelines of 22 December 2023, received from members of the small intersessional working group. The changes made to the technical guidelines adopted by the Conference of the Parties of October 2011 have been tracked so that the revisions can be easily identified. Most of the changes made to the version of the draft guidelines of 22 December 2023 are highlighted in grey. The present note, including its annex, has not been formally edited.

* UNEP/CHW/WPT_SIWG.1/1

Annex

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

(Version of 23 February 2024)

Contents (to be updated)

Abbreviations

ASTM	American society for testing and materials

BAT	Best available techniques
BEP	Best environmental practices
BR	Butadiene Rubber
CAGR	Compoud annual growth rate
CAS	Chemical Abstract Service
CEN	European committee for standardization
CEDR	Conference of European Directors of Roads
CLP	Classification, Labelling and Packaging
ECHA	European Chemical Agency
WASTE TYRE	End of life tyres
EMS	Environmental Management System
EPA	Environmental protection agency
EPR	Extended producer responsibility
ESM	Environmentally sound management
ETRMA	European Tyre and Rubber Manufacturers Association
EU	European Union
GEF	Global Environment Facility
GEMS	Global environment monitoring system
GHS	Global Harmonized System of Classification and Labelling of Chemicals
IATA	International air transport association
ICAO	International Civil Aviation Organization
IMO	International maritime organization
IRGS	International Rubber Study Group
ISO	International organization for standardization
ISWA	International solid waste association
LCA	Life Cycle Analysis
MP	Microplastic
MRP	Micronized Rubber Powder
MSW	Municipal solid waste
NR	Natural Rubber
OECD	Organisation for economic co-operation and development
PAHs	Polycyclic Aromatic Hydrocarbons
PM2.5	Particles below 2.5 µm in air
PM10	Particles below 10 µm in air
POP	Persistent organic pollutants
REACh	Regulation (EU) 1907/2006 on Registration, Evalutaion, Authorisation and Restriction of Chemicals (reach Reulation)
RIVM	Dutch National Institute for Public Health and the Environment
RoHS	Restrictions of Hazardous Substances
RWP	Road wear particles
SAICM	Strategic Approach to International Cheical Management
SDS	Safety Data Sheet
TCLP procedure	Toxicity characteristic leaching
TP	Tyre particles
TWP	Tyre wear particles
TRWP	Tyre and road wear particles
UNDP	United Nations Development Programme
UNECE	United Nations Economic Commission for Europe
UNIDO	United Nations Industrial Development Organization
USEPA	Environmental Protection Agency (United States of America)
WHO	World Health Organization

Units of measurement

µg	microgram
mg	milligram
g	gram

kg	kilogram
mg/kg	milligram(s) per kilogram. Corresponds to parts per million (ppm) by mass.
L	Liter
m3	cubic meter
cm3	cubic centimeter
°C	degree Celsius
Ppm	parts per million
Tonne	1000kg

I. Introduction

A. Scope

1. The present technical guidelines provide guidance on the environmentally sound management (ESM) of used and waste pneumatic tyres, pursuant to decision BC-15/15 and BC-16/7 of the Conference of the Parties to the Basel Convention on the Control of Transboundary Movement of Hazardous Wastes and Their Disposal. This document supersedes the revised technical guidelines for the environmentally sound management of used and waste pneumatic tyres of October 2011.

2. Waste tyres, in the context of these guidelines, covers waste pneumatic tyres, excluding those destined for Annex IVA operations.

3. These technical guidelines do not cover guidance on plastic waste containing or contaminated with POPs as such guidance is covered by the general technical guidelines on the ESM of wastes consisting of, containing or contaminated with Persistent Organic Pollutants (POPs) (UNEP, 2019a), technical guidelines on unintentionally produced POPs (UNEP,2017a) and the specific technical guidelines on HBCD (UNEP, 2017b), POP-BDEs (UNEP, 2019b), PFOS and PFOA (UNEP, 2023) and SCCPs (UNEP, 2018c). These technical guidelines also do not cover guidance on the co-processing, incineration and landfilling of plastic waste as such guidance is covered by the technical guidelines on the environmentally sound co-processing in cement kilns (UNEP, 2011), the technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022a) and the technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5) (UNEP, 2022b), respectively.

4. It should be noted that several other technical guidelines also provide guidance on used and waste pneumatic tyres, as follows:

(a) For specific guidance on waste tyres containing or contaminated with POPs, see Basel Convention general technical guidelines on the ESM of wastes consisting of, containing or contaminated with Persistent Organic Pollutants (POPs) (UNEP, 2023a), technical guidelines on unintentionally produced POPs (UNEP,2017a) and the specific technical guidelines on HBCD (UNEP, 2017b), POP-BDEs (UNEP, 2019b), PFOS and PFOA (UNEP, 2023) and SCCPs (UNEP, 2018c).

(b) For specific guidance on the co-processing of waste tyres in cement kilns, see the Basel Convention technical guidelines on the environmentally sound co-processing in cement kilns (UNEP, 2011)

c) For specific guidance on the landfilling of waste tyres, see the Basel Convention technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes in specially engineered landfill (D5) (UNEP, 2022b)

(d) For specific guidance on the incineration of waste tyres, see the technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022a) .

(e) Technical guidelines on the environmentally sound disposal of hazardous wastes and other wastes as covered by disposal operations D10 and R1 (UNEP, 2022a)

B. About tyres

5. According to IRSG (International Rubber Study Group) research, it is estimated that the total production of tyres of the world in 2021 was 16.87 million tons, increased by 9% from the previous year.[1]

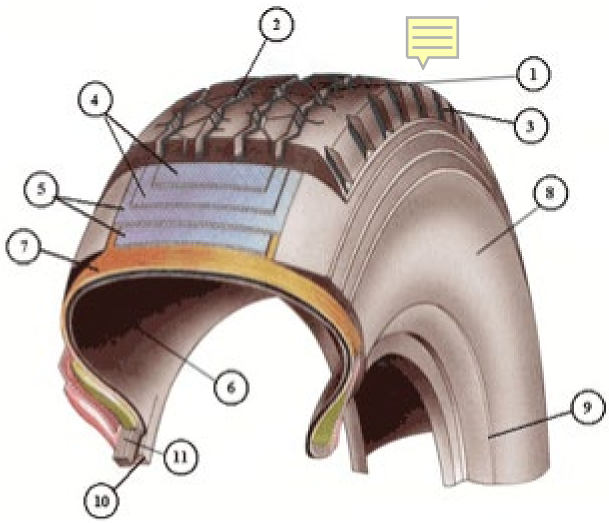
6. The Future of Global Tires to 2022 estimates the overall market to reach over 2.2 billion units by 2017 with volume growth is expected to continue, at a 3.4% compound annual rate from 2017 through to 2022[2]; in 2022 total global industry tire volume is seen as approaching 2.7 billion units. The Global Tire Market size is valued at around USD 232 billion in 2023 and is estimated to grow at a CAGR of about 4.11% during the forecast period, i.e., 2024-29. With the emergence of more efficient vehicles and a smoother infrastructure, the market is experiencing rapid growth & changes. ~~The Global Tire Market size is valued at around USD 232 billion in 2023 and is estimated to grow at a CAGR of about 4.11% during the forecast period, i.e., 2024-29. With the emergence of more efficient vehicles and a smoother infrastructure, the market is experiencing rapid growth & changes.~~ The rise in vehicle production in developing countries & increased competition among tire manufacturers are the prime aspects projected to drive the market in the forecast years.

1. Structure: tyre components and definitions of technical terms

7. 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, end of life 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[3].

8. 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



[1] https://rubberworld.com/international-rubber-studies-group-release-latest-industry-outlook/ and https://www.rubberstudy.org/reports

[2] https://www.reportlinker.com/market-report/Tire/6303/Tire?term=tire%20industry&matchtype=b&loc_interest=&loc_physical=9181214&utm_group=standard&utm_term=tire%20industry&utm_campaign=ppc&utm_source=google_ads&utm_medium=paid_ads&utm_content=transactionnel-4&gad_source=1&gclid=Cj0KCQiAw6yuBhDrARIsACf94RXh19G-hJjapQfzVx4mJlvaKSqEEloLEny_bBN

[3] Passenger car type approval regulation: UN ECE Regulation 30; Truck tyre type approval regulation: UN ECE Regulation 54; Motorcycle tyre type approval regulation: UN ECE Regulation 75; Agricultural Tyre type approval regulation: UN ECE Regulation 106: UNECE - Regulation 117 and its successive amendments EU Regulation 2019/2144

waste tyre

(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) **"Bwaste tyre" (9)** refers to a radial ply or bias-bwaste tyreed 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.

9. The most common types of tyre structure are diagonal (cross-ply), bias-bwaste tyreed and radial. Almost 80 per cent of all tyres sold are radial tyres and 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.

2. Natural rubber and synthetic rubber

9bis. Rubber is a flexible, resilient material, composed by elastomers. Elastomers are a subclass within polymers; an el9biastomer is defined as a cross-linked, amorphous polymer. Elastomers are highly elastic and viscous polymers formed by long molecules in the form of long carbon, hydrogen, oxygen or silicon chains, whose chemical structures have intermolecular cross-links and can recover their original shape after being stretched. Thermosetting elastomers are used to manufacture tires

10. Natural rubber is obtained from a tree called Hevea brasiliensis as an aqueous suspension. It is a natural biosynthesis polymer and is mainly known for its excellent high tensile strength, unlike most of the other polymers. In addition, natural rubber has greater structural regularity, higher green strength and a faster vulcanization rate. Owing to this fast rate of vulcanization, natural rubber has become one of the most important raw materials in many industries including tyres, gloves, rubber carpets, etc. Despite its excellent properties, natural rubber shows very poor resistance to atmospheric oxygen, ozone, oils, and various hydrocarbon solvents. Some more properties of natural rubber include ease of processing, excellent dynamic performance with a low hysteresis loss, good low-temperature properties, ability to bond metal parts, high tear and abrasion resistance, good dynamic performance, low heat buildup during heating and low level of damping.

11. Synthetic rubbers are man-made rubbers. The raw materials for the production of synthetic rubbers are mainly obtained as the by-products of crude oil production. Either solution or emulsion polymerization techniques are used to synthesise synthetic rubbers. Unlike natural rubber, the properties of these rubbers can be fabricated according to the final requirement by applying various polymer chemistry techniques. For example, we can develop synthetic rubbers with excellent weather, chemical, temperature and solvent resistance.

Table 1

. Difference between natural rubber and synthetic rubber

Natural Rubber	**Synthetic rubber**
Natural rubber is a natural biosynthetic polymer obtained from a tree	Synthetic rubber is man-made polymers under controlled conditions
Naturally occurs in the plant cells	Synthesised from crude oil by-products by using solution or emulsion polymerization techniques
Monomers include cis-1,4-isoprene	Monomers are different in each synthetic rubber type
Properties are difficult to change	Properties can be adjusted to suit the final application

3. Tyre composition

12. Tyres are composed of a variety of components such as rubber, carbon black and silica, metal, textiles, zinc oxide, sulphur, and other additives. The proportion of these components in a new tyre are shown in Table 2. The components of a new tyre are shown in table 1, and the materials used in its manufacture are shown in table 3.

Table 2. **Main components of car and truck tyres (in %)**

~~Material~~	~~Automobile (%)~~	~~Trucks (%)~~
~~Natural rubber~~	~~22~~	~~30~~
~~Synthetic rubber~~	~~23~~	~~15~~
~~Carbon black and silica~~	~~28~~	~~24~~
~~Metal~~	~~13~~	~~25~~
~~Textile~~	~~5~~	
~~Zinc oxide~~	~~2~~	~~2~~
~~Sulphur~~	~~1~~	~~1~~
~~Accelerators/antidegradants~~	~~2,5~~	
~~Stearic acid~~	~~1~~	
~~Additives~~	~~12~~	~~10~~

Source: https://www.etrma.org/wp-content/uploads/2019/09/etrma-imds-vulcanised-rubber-pseudo-susbtances-tyres-guidance-2.pdf.and https://www.ustires.org/innovation

Material	**Automobile (%)**	**Trucks (%)**
Natural rubber	21	37
Synthetic rubber	22	10
Carbon black and silica	28	24
Metal	13	22
Textile	5	0,2
Zinc oxide	2	2
Sulphur	1	1
Accelerators/antidegradants/antioxidants,	2	3
Stearic acid	1	

Oils	7	0,8

Source : https://www.ustires.org/whats-tire-0 and https://www.etrma.org/wp-content/uploads/2019/09/etrma-imds-vulcanised-rubber-pseudo-susbtances-tyres-guidance-2.pdf. https://www.sciencedirect.com/science/article/pii/S2542504822000392

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

Table 3.
Materials used in the manufacture of tyres

Material	Properties	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	Synthetic rubbers are made from petrochemicals. ~~Also, synthetic rubbers are made by recycled process~~	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. Moreover, carbon black derives from recycled process, and it is defined as rCB. Pyrolisis is the technologies that allows to recovery carbon black from tyres	Carbon black and silica provide durability and resistance against wear and tear. Both rCB and bio-based silica from rice husks are already used in serial production
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. In rubber sulphur crosslinks are irreversible as they bridge the rubber chains permanently
Resorcinol Formaldehyde	Resorcinol glue, also known as resorcinol-formaldehyde, is an adhesive combination of resin and hardener that withstands long-term water immersion and has high resistance to ultraviolet light.	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 bwaste tyre.
Oils: Aromatic oil, plant based oil (soybean oil), MES (special purified, aromatic oil), Naphthenic oil, TDAE (special purified aromatic oil) , Paraffinic oils	Paraffinic mineral oils have the following natural properties: - high flash point, especially in their highest grades of viscosity. - chemical inertia regarding metals and their alloys as free from any additives. - compatibility with other oils: being pure minerals they can be mixed with other oils, be they pure or additivated; - high viscosity index: changes in viscosity are limited with changes in temperature. Oil becomes moderately viscous at	Oils enter into the composition of tyres because they are required to facilitate the processing of the rubber compounds. They are also an essential component for the technical performance of the tyre and in particular for its road adherence (or grip) properties. They therefore contribute and directly play a part in the quality of the tyre and user safety. (https://www.etrma.org/wp-content/uploads/2019/09/20100712-etrma-qanda-replacement-of-ha-oils-in-tyres.pdf)

Material	Properties	Application
	relatively low temperatures and not too fluid at high ones. - pour point is sufficiently low and adequate for generic lubrication in not particularly rigid winter conditions; - high thermo-oxidative stability: resistance to molecular breaking (pyroscission or cracking) and degradation at high temperatures. Plant base oil (soybean oil) can improve the pliability of a tire at low temperatures	
Other additives and solvents Heterocyclic compounds, Phenylene-diamine derivatives, Phenolic stabilizers, Sulphenamides, Guanidine derivatives, Thiazoles, Dithiophosphates, Thiurams, Dithiocarbamates, Thioureas, Rubber Processing Chemicals	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.
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

14. Tyres vary in weight according to their composition and use. Table 4 provides information on the most common categories.

Table 4.
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).

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15. ~~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[7] 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;

(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.

16. 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.

17. ~~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.~~ When waste tyres improperly managed and disposed of, they may pose risks to public health and the environment. For example, tyres are not biodegradable because the time that they take to decompose is indeterminate.

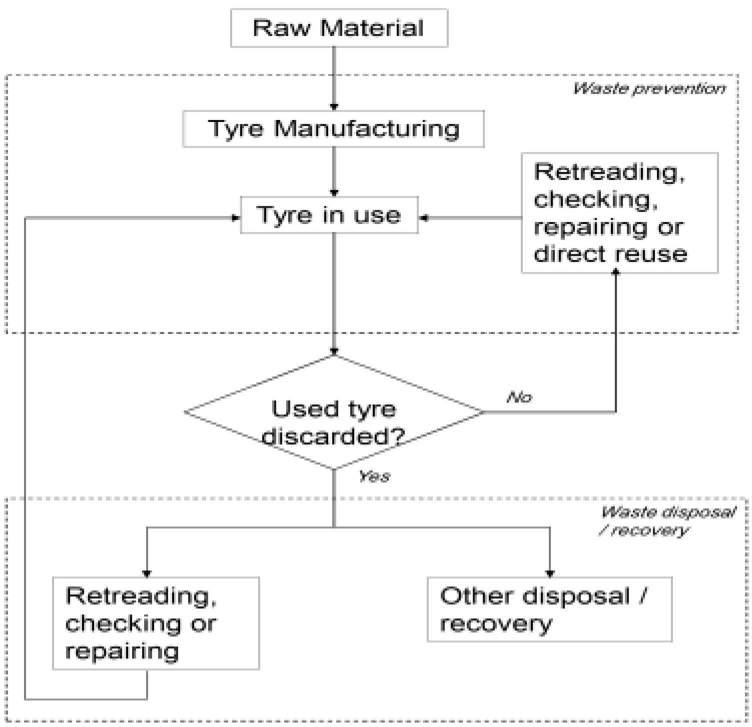
18. ~~Tyres are not biodegradable because the time that they take to decompose is indeterminate. Used~~ End-of-life tyres and waste tyres ~~represent waste that~~ takes up much physical space and are difficult to compact, collect and dispose. In addition to the visual impact, inadequate disposal can 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.

C. Stages in the life of a tyre

19. The various stages in the life of a tyre, from when raw material, including both virgin and secondary raw material is acquired through to manufacture, use and disposal/recovery, are shown in figure II..

Figure II
Stages in the life of a tyre

[7] HR Wallingford (2005).



1. Used pneumatic tyres

20. 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.

21. 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.

2. Retreaded tyres

22. The term "retreading" refers to 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. The retreading process is considered as s a way of increasing the

useful life of tyres and may be considered a reuse measure within the waste management hierarchy. As shown in Figure II, retreading may take place in the prevention phase as a re-use measure or in the waste disposal phase where used tyres that have been disposed of may undergo retreading as a waste recovery operation, thus increasing the useful life of tyres through retreading in both phases. Further information on retreading technologies is presented in section F of chapter III of the present guidelines.

3. Waste pneumatic tyres

23. A waste tyre is one which is is disposed of or is intended to be disposed of or is required to be disposed of by the provisions of national law. A waste tyre is typically but not exclusively a tyre that reaches end-of-life and can no longer serve its original purpose on a vehicle. Used tyres that can still legally serve their purpose on a vehicle can be designated for scrap, and thus become waste tyres prematurely. A newly produced tyre that does not meet quality standards and is therefore not suitable for use on a vehicle is also a waste tyre.

Waste 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. Around 50% of waste tyre's in EU are mechanically recycled to recover their high-value materials

24. The recovery of waste tyre generates rubber shreds, chips, granulates, pellets and powder. This process is called granulation, and it is a recovery method which involves the breaking down of waste tyre into smaller particles through different processes to obtain rubber granulate and powder, used in multiple applications. After shredding and removal of the steel and fabric components, the remaining rubber is reduced to rubber granules. The micronized rubber powder (MRP) is classified as fine, dry, powdered elastomeric crumb rubber in which a significant proportion of particles are less than 100 µm and free of foreign particulates (metal, fiber, etc.). MRP particle size distributions typically range from 180 µm to 10 µm.

25. Applications of rubber recovered from waste tires (shreds, chips, pellets, granulates, powders,) include many sectors, as defined in Table 10, such as wheels for caddies, dustbins, wheelbarrows and lawnmowers, urban furniture and signposts. Rubber recovered from waste tires is also to be found as flooring for playgrounds, as athletic tracks, as shock absorbing mats for schools and stables, as paving blocks or tiles for patios and swimming pool surrounds as well as roofing materials. One of the main uses of granules is rubber infill of artificial turf. This is a synthetic surface of fibres made to look like grass, used in sports arenas different outdoor environments, such as residential lawns, schools and playgrounds. MRP is used in many applications of molded rubber products and other "open-loop" applications and has been used since the 2000s in rubber mixes to make new tires, a "closed-loop" application.

25bis. As regards intentionally added synthetic polymer microparticles, European Commission with REGULATION (EU) 2023/2055 of 25 September 2023 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)[8] starting from 2031~~, has introduced several restriction options for granular infill for use on synthetic sports surfaces and a ban was established on the placing on the market as substances on suggested their own or, where the synthetic polymer microparticles are present to confer a sought-after characteristic, in mixtures in a concentration equal to or greater than 0,01 % by weight from 17 October 2031~~. has introduced a ban on the placing on the market of granular infill made of synthetic polymer microplastics for use on synthetic sports surface from 17 October 2031.

[8] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R2055

D. Tyre and Road wear particles

26. Tyre and road wear particles (TRWP) are a mixture of tyre tread fragments and road surface elements, such as minerals and road dust. Generated by the friction between roads and tyre surfaces, they are the result of normal use of a tire caused by friction between tire tread and road surface (contributing to safety aspects, such as breaking performance of tires). It is important to note that TRWP are generated by tyres as a product in use and are not produced by ELT or materials derived from ELT. Because of their size and composition, TRWP are commonly associated with microplastics.

TRWP are a dynamic field of research, They have a unique structure and composition because they are generated by abrasion, while rubber granulates made from recycled tires are produced by other industrial methods. The process of abrasion should not be equated to recycling methods that produce granulates and other materials. For this reason, risks identified by TRWP research should not be considered equivalent to risks of ELT applications.

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E. Potential risks to human health and the environment at end of life

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28bis. Waste tyre or materials recovered from waste tyres (granules and powder recovered by waste tires) could generate the potential impacts on human health and the environment, some of which are still being further investigated . The following considerations are of relevance:

(a) In landfills, waste 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.[23] It is for this reason that tyres have been banned from disposal in landfills in the European Union.[24]

(b) 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 leach toxic contaminants that affect the soil, waterways and air. [25] The contaminants that are released include PCBs, dioxins and furans.[26]

(c) Materials recovered from waste tires (granulates), could be released in the environment,. ECHA has investigated the available information on substances found in recycled rubbergranules used as infill material in synthetic turf. These rubber granules are regarded as mixtures and contain a wide variety of substances depending on the material from which the granules are produced (recycled). The granules also contribute to microplastic pollution as they can be spread to the environment from the pitches, for example, through rainwater or players' footwear and clothing.

(d) The presence in waste tyres and materials recovered from waste tyres of hazardous substance such as oils (PHAs) and their release to the environment.

(e) The abandonment of waste tyres in the environment could create related damage to the environment in relation to the fact as mentioned for landfill.

(f) Breeding Ground for Pests: Discarded tires can provide a breeding ground for mosquitoes, rodents and other pests, which can lead to increased health risks.

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

1. Risks to public health

30. Regarding the use of recycled rubber granulates for artificial turf on sport pitches or for playground surface areas, multiple studies (RIVM 06, RIVM 2016, ECHA 2017, ERASSTRI 2020 etc.) conclude that the health risk related to playing sports or using playgrounds on surfaces is negligible. Human health assessments of infill material have been carried out in the European Risk Assessment Study on Synthetic Turf Rubber Infill (ERASSTRI project), which concluded that there are no relevant health concerns derived from the use of the material in sports fields and even in work places related with the treatment of ELT.

On 2 November 2018, ECHA sent to the Commission a paper outlining the approach and results of the prioritisation of substances in infill material for synthetic sports surfaces for further human health risk assessment. The outcome of the prioritisation was that 12 candidate substances were selected for further human health risk assessment. A preliminary human health risk assessment of the 12

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23 Directive 1999/31/CE.

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

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

26 https://www.eea.europa.eu/publications/EMEPCORINAIR5/Sources_of_PCB_emissions.pdf/view https://www.diva-portal.org/smash/get/diva2:962334/FULLTEXT01.pdf

substances followed. ECHA concludes that the risks from exposure to chromium (Cr), nickel (Ni), selenium (Se), beryllium (Be), magnesium (Mg), vanadium (V), lithium (Li) and mercury (Hg) from playing on pitches with artificial rubber infill can be considered negligible. No further human health risk assessment on these metals will be undertaken.[27]

31. ECHA has concluded that based on the available information, with the concentrations of polycyclic aromatic hydrocarbons (PAHs) found to be typically present in rubber crumb recycled from waste tires used as infill in synthetic sports fields), the concern for excess lifetime cancer risk for players and workers is very low.[28]

32. According to the ECHA Guidance concerning dose (concentration) response to human health, the cancer risk decision points used for lifetime exposure of the general population to rubber crumb recycled from waste tyres used as infill are generally in the range of 10-5 to 10-6 . There is no formal maximum limit but an excess cancer risk of 10-6 was seen as an acceptable level of risk.

33. In studies ECHA has evaluated the concentrations of PAHs in rubber granules recycled from waste tyres (considered as mixtures) have normally been well below the limit values set in the REACH restriction relevant for such mixtures. The studies covered approximately 50 samples from new recycled rubber granules and several hundreds of samples taken from more than 1000 fields. The samples were from different Member States, e.g. from Finland, Italy, the Netherlands, Portugal and United Kingdom. In addition, ECHA received studies from industry, which investigated PAHs from different fractions of tyres. It is important to note, however, that if the concentration of PAHs would be as high as the generic limit for mixtures supplied to the general public defined in REACH, the level of concern would not be low.

34. ECHA concludes that the limit of 20 mg/kg for the sum of REACH-8 PAHs established for rubber granules and mulches in loose form can be considered protective for children for use in playgrounds. In line with RAC's opinion on the restriction proposal on rubber granules (ECHA, 2019d), ECHA considers also that such limit helps to significantly reduce children's exposure to PAHs by preventing the use of rubber granules and mulches with high PAH content in the EU.

Tyre granulates can also contribute to pollution as they can be spread to the near vicinity of the pitches, for example, through rainwater or players' footwear and clothing. The risk of exposure to granulates can be controlled by implementing mitigation measures, including the installation of borders and transition zones to collect granules falling off footwear.

35. 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.

36. 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.

37. 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.

38. *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

[27] HH and ENV (europa.eu)

[28] Final (europa.eu)

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.[29]

39. 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.

40. Chapter 5 of the World Health Organization publication: *Dengue haemorrhagic fever: diagnosis, treatment, prevention and control*,[30] 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.

41. The production of shredded tyres also minimizes the risk of providing breeding sites for mosquitoes.

2. Environmental risks

42. 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.

43. ~~In 2006 RIVM performed a risk assessment of rubber granulate on synthetic turf pitches based on existing knowledge and literature. It included a report by the Danish Environmental Protection Agency. Based on the data available at the time and the selected exposure scenario, it was concluded that the health risk due to exposure to polycyclic aromatic hydrocarbons (PAHs) in rubber granulate is negligible.~~

44. In the initial list of identified substances pointed out by ECHA from the Document *Federal Research on Recycled Tire Crumb Used on Playing Fields-* EPA 2016, there were several (non dioxin-like) PCBs, but they were not prioritised. As stated in RIVM (2017), the total concentration of the seven different PCBs is above the soil limit for residential classification in the Netherlands (0.04 mg/kg). Therefore, ECHA proposes that in any future assessments as regards environmental risks of infill materials, relevant combined or mixture effects of substances should be considered. Based on the risk screening of prioritised substances, ECHA concludes that there is a need to further assess the risks to the environment of the following substances found in infill material: cadmium, cobalt, copper, lead, zinc, 4-tert-octylphenol, 4,4´-isopropylidene diphenol (BPA), bis(2-ethylhexyl)phthalate (DEHP), benzyl butyl phthalate (BBP) and benzothiazole-2-thiol.[31]

(a) Ecotoxicity

45. The ecotoxicity of waste tyres is challenging to evaluate. The potential ecotoxicity related to waste tyres would cover the following scope: tyre fires, uncontrolled dumping, disposal operations and use of tyre-derived materials in land based applications. 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

[29] Health Canada.

[30] WHO, second edition (1997).

[31] HH and ENV (europa.eu)

chemicals assessed and the evaluation methodology. Gaps remain in the scientific knowledge regarding the ecotoxicity of tyres..

46. [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.

47. In 2003, tests conducted by Birkholz in California[32] 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.

48. 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,[33] thereby influencing the population dynamics of wood frogs, for example.[34]

In 2022, research (Magni et al 2022) conducted in Italy under UNI for recyclers of ELT to comply with the criteria set out under REACH and CLP, concluded regarding the ecotoxicity of rubber granulates and powders that neither can be classified in the context of CLP regulation, either for short-term aquatic hazard or for long-term aquatic hazard for all trophic levels.

49. 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.[35]

50. 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) 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.]

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

33 Stephensen, Eiríkur and others (2003).

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

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

(b) Leaching

51. Leaching is a process by which a chemical substance is removed or transferred from a material, especially soil, by the action of water passing through the material. Leachate is any contaminated liquid generated from water percolating through a solid waste disposal site or stockpiled or buried materialaccumulating contaminants, and moving into subsurface areas. Water generated by waste 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[36] has identified several factors that may affect the rate of leaching and/or the concentration of waste tyre leachate compounds in soil, surface water and groundwater.

52. [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.

53. [Three recent studies have examined the environmental aspects of using tyre granulates as filler for synthetic sportsfields.[37] These studies researched the elements and chemical substances found in the composition of the filling materials, and more particularly those made from end-of-life 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 end-of-life tyres is not likely to affect water resources in the short and medium term.

54. 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.]

55. 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.[38] 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 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

36 MWH (July 2004).

37 Aliapur and others (2007).

38 INTRON report A845090/R20090029, "Adsorption of zinc to synthetic turf underlays" (2009).

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 artificial turf field, with environmentally sound management, there is limited risk to the environment due to the leaching of zinc.

56. 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.][39]

57. Some literature on the potential of chemicals to leach from end-of-life 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.[40]

(c) Uncontrolled open air burning

58. Tyres do not spontaneously combust. If, however, a fire breaks out, either because 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.

The physical properties of rubber tyres create difficulties in extinguishing burning tyres. The shape of tyres and the tyres stacking arrangement result in many three-dimensional pockets which are difficult to access or penetrate with extinguishing mediums. Rubber also naturally repels water thus resulting in extinguishing mediums shedding from the tyre and draining away.

59. 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).

60. 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.

39 Aliapur and others (2007).

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

61. 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.

62. 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.[41] Table 5 describes the composition of the smoke.

[41] 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

(i) Air pollution

63. 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.[42]

64. The leachate of such pollutants with rainwater could potentially 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). However no conclusive information is available at this time.

(ii) Water pollution

65. If stockpiles of waste tyres are burned, in uncontrolled conditions 1 million tyres (~12,500 tons) may generate over 200,000 litres (~180 tons) of run-off oil, as tyre combustion causes partial breakdown of the rubber waste, which results in oily decomposition waste that is both highly polluting

[42] Reisman, Joel I. (1997).

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, and polycyclic aromatic hydrocarbons may also be present. The fire prevention measures outlined above would avoid or reduce impacts to water bodies or resources.

(iii) Soil pollution

66. 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 and international linkages

A. Basel Convention

1. General provisions

67. The Basel Convention, which entered into force on 5 May 1992, aims to protect human health and the environment against adverse effects resulting from the generation, management, transboundary movements and disposal of hazardous and other wastes. It does this via s et of provisions on the transbiunbdary movement of wastes and their environmentally sound management (ESM). In particular, the Basel Convention 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.

68. 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 lawArticle 2, Paragraph 4 defines disposal as "any operation specified in Annex IV" to the Convention. Annex IV contains two categories of operations: those leading to the possibility of resource recovery, recycling, reclamation, direct reuse or alternative uses (R operations) and those not leading to this possibility (D operations).Paragraph 8, it defines theESM 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".

69. 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)".

70. Article 4, paragraphs 2 (a)–(e) and (g), and paragraph 8, containe 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.

Paragraph 2 (a) and (e) and 2(g):"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.

Paragraph 8: "Each Party shall require that hazardous wases or other wastes, to be exported, are managed in an environmentally sound manner in the State of import or elsewhere."

71. The Ban Amendment entered into force on 5 December 2019, and it provides that Parties listed in Annex VII to the Convention (members of the European Union, OECD and Liechtenstein) shall prohibit transboundary movements to States not listed in Annex VII of hazardous wastes which are destined for operations according to Annex IV.A and hazardous wastes under Article 1, paragraph 1(a) which are destined for operations according to Annex IV.B9 .[43]

2. Provisions relevant to tyres[44]

72. According to article 1 ("Scope of the Convention"), the Basel Convention covers two types of waste subject to transboundary movement: "hazardous wastes" and "other wastes".

73. Paragraph 1 of Article 1 reads as follows:

(a) Wastes that belong to any category contained in Annex I, unless they do not possess any of the characteristics contained in Annex III; and

(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."

74. .

75. Waste 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 (Y16-Y45). These are encased in the rubber compound or may be present as an alloying element; they are shown in table 6. Tyres are unlikely to spontaneous combustion and are therefore not classified as flammable pursuant to characteristics H4.1–4.3 of Annex III to the Basel Convention.

[43] For information on the status of individual Parties in relation to the amendment/s, please see the Status of Ratifications page on the Basel Convention website)."

[44] For information on the status of individual Parties in relation to the amend ment, please see the Status of Ratifications page on the Basel Convention website.

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~~
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~~

76. 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 documents for Annex III hazardous characteristics H6.1, H11, H12 and H13 were adopted on an interim basis by the Conference of the Parties to the Basel Convention at its sixth and seventh meetings.

103bis. At its fourth meeting in February 1998, the Conference of the Parties added the two lists of wastes as two new annexes to the Convention, namely Annex VIII (list A) and Annex IX (list B). These were intended to provide greater certainty and clarity to the entries. List A and List B are kept under review by the Conference of the Parties; in addition, a process was established under Decision BC VIII/15 of the Conference of the Parties to the Basel Convention to facilitate the identification and agreement on new entries.

77. 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”. However, Annex I and Annex III remain the factors to characterize wastes as hazardous for the purpose of this Convention, and that List A and List B are not intended to be exhaustive[45]

78. 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. .

79. As stated in Article 1, paragraph 2, “Wastes that belong to any category contained in Annex II that are subject to transboundary movement shall be “other wastes” for the purposes of this Convention. Annex II entry Y46: wastes collected from households may be applicable to waste pneumatic tyres.

80. 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. . There is no Annex VIII or Annex IX entry for waste pneumatic tyres destined for Annex IV.A operations.

B. International linkages

1. Work under UNEA on marine plastic litter and microplastics

81. Concerns about global tyres particle, microplastics and the related risks to human health and the environment are increasing. The negative effects on the marine and ocean environment have been globally agreed and governments are committing to reducing plastic pollution. Four resolutions on marine plastic litter and microplastics have been adopted by the United Nations Environmental Assembly (UNEA) on its sessions in 2014, 2016, 2017 and 2019 to address the challenges and the issue has also been addressed in separate resolutions, hereunder on waste management and on single-use plastics in 2019.

82. UNEA-1 resolution 6 on “Marine plastic debris and microplastics”[46] formally brought the issue on UNEA’s agenda and emphasized the challenges of plastic and microplastic, the need for urgent action and further information and research and encouraged multi-stakeholder engagement. (UNEP, 2014).

83. UNEA-2 resolution 11 on “Marine plastic litter and microplastics”[47] addressed the challenges related to marine litter, hereunder issues of microplastic and nano-size particles, transport of plastic

[45] Guide to the control system, Basel Convention, 2015 (UNEP, 2015e) Available from http://www.basel.int/Implementation/Publications/GuidanceManuals/tabid/2364/Default.aspx

[46] UNEA-1 (2014). res. 6 “Marine plastic debris and microplastics” https://www.unep.org/environmentassembly/proceedings-and-report-resolutions-and-decisions-unea-1?%2Fproceedings-report-ministerial-dialogue-resolutions-and-decisions-unea-1=

[47] UNEA-2 (2016). res. 11 “Marine plastic litter and microplastics” https://www.unep.org/environmentassembly/proceedings-report-resolutions-and-decisions-unea-2

through freshwater systems, the slow degradation processes and the release and adsorption of chemicals such as POPs (UNEP, 2016).

84. In 2017, UNEA-3 resolution 7 on "Marine litter and microplastics"[48] addressed the importance of preventive actions through waste minimization, environmentally sound waste management and actions in geographical areas with large sources of marine plastic litter and recognized that measures exist to provide cost-effective solutions (UNEP, 2017c).

85. The resolution also established an open-ended ad hoc expert group (AHEG) to further examine barriers to and options for combating marine plastic litter and microplastics. The AHEG discussed the adequacy of existing global governance frameworks (UNEP/AHEG, 2018a), and addressed issues related to information, monitoring and governance and possibilities for new governance structures for marine plastic litter (UNEP/AHEG, 2018b). In addition, at its third and fourth AHEG meetings in November 2019 and November 2020 AHEAG delivered results of the stocktaking of existing activities and effectiveness of existing and potential responses to address marine litter issues providing opportunities for collaboration. In 2020, AHEG has completed its mandate.

86. UNEA-4 resolution 6 on "Marine plastic litter and microplastics"[49] addresses development of indicators to harmonize monitoring, the need for effective monitoring of sources, quantities and impacts of marine litter and invited member states to promote environmentally sound waste management and marine plastic litter recovery (UNEP, 2019a). UNEA-4 res. 9 on "Addressing single-use plastic products pollution"[50] encourages member states to develop and implement actions to address environmental impact of single-use plastic products, identify alternatives to single-use plastics, promote improved waste management and more resource-efficient design, production, use and sound management of plastics across their life cycle (UNEP, 2019b).

87bis. UNEA-5 res. 5/14 "End plastic pollution: Towards an international legally binding instrument on plastic pollution" established an intergovernmental negotiating committee (INC) to develop a new international instrument on plastic pollution, including in the marine environment, and to conclude its work by the end of 2024. The resolution specifically addresses the transboundary nature of the problem of plastic pollution, in marine and other environments, and that it needs to be tackled, together with its impacts, through a full-life-cycle approach. It also explicitly states that plastic pollution includes microplastics.[51]

2.

87.

III. Guidance on environmentally sound management

A. General considerations

88. waste tyre. ESM is a broad policy concept that is understood and implemented in various ways by different countries, organizations and stakeholders. The provisions and guidance documents pertaining to the ESM of hazardous wastes and other wastes under the Basel Convention provide for a

[48] UNEA-3 (2017c). res. 3 "Marine litter and microplastics" https://www.unep.org/environmentassembly/proceedings-report-ministerial-declaration-resolutions-and-decisions-unea-3

[49] UNEA-4 (2019a). res. 6 "Marine plastic litter and microplastics". https://www.unep.org/environmentassembly/proceedings-report-ministerial-declaration-resolutions-and-decisions-unea-4

[50] UNEA-4 (2019b). res. 9 "Addressing single-use plastic products pollution". https://www.unep.org/environmentassembly/proceedings-report-ministerial-declaration-resolutions-and-decisions-unea-4

[51] https://wedocs.unep.org/handle/20.500.11822/40597

common understanding and international guidance to support and implement the ESM of hazardous wastes and other wastes. The OECD has also produced core performance elements related to ESM

1. Basel Convention

waste tyre

89. 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.

90. The 2013 Framework for the environmentally sound management of hazardous wastes and other wastes, adopted by decision BC-11/1 (“ESM framework”) establishes a common understanding of what ESM encompasses and identifies tools and strategies to support and promote the implementation of ESM. In addition, a set of practical manuals for the promotion of the environmentally sound management of wastes (UNEP/CHW.13/4/Add.1/Rev.1 and UNEP/CHW.14/5/Add.1) has been developed. The ESM framework and the practical manuals are intended as practical guides for governments and other stakeholders participating in the management of hazardous wastes and other wastes and complement the Basel technical guidelines. Moreover, guidance on how to address the environmentally sound management of wastes in the informal sector (UNEP/CHW.14/INF/8) and a practical manual for stakeholders to ensure that notifications of transboundary movements meet environmentally sound management requirements (UNEP/CHW.15/[…]) are being developed.

91. As presented in paragraph 32 of this document, Article 4 of the Basel Convention contains provisions related to the ESM of hazardous wastes and other wastes. ESM is also the subject of the following declarations:

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

(b) The 2011 Cartagena Declaration on the Prevention, Minimization and Recovery of Hazardous Wastes and Other Wastes, which was adopted at the tenth meeting of the Conference of the Parties to the Basel Convention and reaffirms that the Basel Convention is the primary global legal instrument for guiding the ESM of hazardous wastes and other wastes and their disposal, including efforts to prevent and minimize their generation, and efficiently and safely manage that which cannot be avoided.

92. The waste management hierarchy is a guiding principle for the ESM of waste and covers prevention, minimization, reuse, recycling, other recovery including energy recovery, and final

disposal is a guiding principle for the ESM of waste. In doing so, encouraging treatment options that deliver the best overall environmental outcome, The hierarchy encourages treatment options that deliver the best overall environmental outcome, taking into account lifecycle thinking.The waste management hierarchy has also been recognised by the Strategic Framework (adopted by decision BC-10/2) the ESM framework (see paras. 11, 14, 18, 26 and 43), and in the Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous and other wastes and their disposal (UNEP, 2017d). [UNEA-2 resolution 11 on marine plastic litter and microplastics, also called on countries to establish and implement necessary policies, regulatory frameworks and measures consistent with the waste hierarchy.[52] The waste hierarchy was also defined and described in UNEP's Global Waste Management Outlook (UNEP, 2015b).]

93. Parties should develop a range of measures (strategies, policies, legislation, regulations and programmes) and monitor their implementation to support the meeting of ESM objectives. The implementation of national strategies, policies and programmes are effective tools to complement the implementation of legislation and regulations; monitoring and enforcement; incentives and penalties; technologies; and other tools in which all key stakeholders participate and cooperate (UNEP, 2013). The following sections should be taken into account when establishing, implementing or evaluating ESM

94.

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

95. In May 2004, theOECD Council adopted recommendation C (2004)100[54] 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;

52

[54] OECD (2004).

(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,[55] which includes the core performance elements.

B. Legislative and regulatory framework

96. 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.

97. Most countries already have in place some form of legislation that outlines broad environmental protection principles, powers and rights. Such legislation should make ESM operational and include requirements for protection of both human health and the environment. Such enabling legislation should give governments the power to enact and enforce specific rules and regulations on the ESM of waste pneumatic tyres, including provisions for inspections enforcement and for establishing penalties for violations (e.g. on illegal traffic).

99bis. Such legislation should enable relevant authorities to monitor whether facilities where waste tyres are disposed of, for example waste tyre recycling facilities, have obtained all the necessary approvals and can demonstrate due diligence in compliance to ensure such facilities are fully protective of human health and the environment. In addition, any legislation should establish whether actors involved in waste tyre management (e.g., collectors, transporters, and recyclers) ensure that the collection, transportation, storage, and disposal of wastes are environmentally sound.

98. The legislation should require adherence to ESM principles, ensuring that countries provide ESM of waste pneumatic tyres, including environmentally sound treatment and disposal as described in the present guidelines. Specific components or features of a regulatory framework that would meet the requirements of the Basel Conventions and other international agreements are addressed in relevant guidance documents developed under these conventions.

99. In addition, Parties should consider a systemic approach to harmonizing and developing policy frameworks related to waste pneumatic tyres. Such an approach may address the root causes of the problem and can take a long-term perspective that considers the long-lasting consequences of tyre in the environment, including the marine environment.

~~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.~~

1. End-of-waste status

100bis. The text of the Basel Convention does not clarify when a waste ceases to be a waste. The Glossary of Terms of the Basel Convention provides explanatory notes in this regard (UNEP, 2017f). Possibilities for waste to cease to be waste referenced in the Glossary of terms include when:

[55] OECD (2007).

a. It has been prepared for reuse;

b. It has undergone a recycling operation and that operation is completed;

c. It has otherwise gained end-of-waste status as a result of a recovery operation.

Some Parties have adopted conditions in their national legislation that can determine the point at which a material need no longer be classified as waste, such as the European Union (European Union, 2008) and the UK (English Environment Agency, 2016

100. After shredding and removal of the steel and fabric components, the remaining rubber is reduced to rubber granules or powder, depending on dimension of tyre rubber.

101. The ingredients of rubber granules and mulches from waste tyre find their basis in tyre manufacturing. The oils that are conventionally used in tyre manufacturing are Highly Aromatic (HA) oils since they are compatible with both natural and synthetic rubbers. Oils in tyres have the functionality of improving processing properties, low temperature properties, dispersion of fillers and to reduce costs. The use of these oils is one of the reasons why PAHs are present in tyres that can, after usage on a vehicle, be processed into WASTE TYRE-derived rubber infill.

102. Several countries have developed national EoW criteria for rubber, recovered from waste tyre , and there are additional regional level EoW criteria in other Member States. Whilst broadly similar, there are differences between them, and only a fraction of EU countries has any form of national-level EoW criteria. Some countries specify end-uses, whereas others do not. Where end-uses are specified, this may have a negative impact on innovation in the sector, by favouring those specified end-uses against emerging end-uses which may be environmentally preferrable.

103. The technical properties of the rubber, recovered from waste tyre,are addressed Technical Specifications or Standards. There are several European Technical Committees that work on creating new Standards related either to recovered materials from waste tyre(CEN TC 366) and to products that commonly use rubber recovered from waste tyre, (e.g. CEN TC 217 for sport and leisure surfaces).[56]

[56] 1. The list of standards below gives examples:

(a) EN 14243-1:2019 (WI=00366004) Materials obtained from end of life tyres - Part 1: General definitions related to the methods for determining their dimension(s) and impurities 2019-02-13

(b) EN 14243-2:2019 (WI=00366006) Materials obtained from end of life tyres - Part 2: Granulates and powders - Methods for determining the particle size distribution and impurities, including free steel and free textile content 2019-02-13

(c) EN 14243-3:2019 (WI=00366007) Materials obtained from end of life tyres - Part 3: Shreds, cuts and chips - Methods for determining their dimension(s) including protruding filaments dimensions • CEN/TR 17511:2020 (WI=00366012) Materials obtained from End-of-Life Tyres - Odour of WASTE TYRE granulates - Origin and remediation possibilities 2020-07-08

(d) CEN/TS 16916:2016 (WI=00366002) Materials obtained from End of Life Tyres - Determination of specific requirements for sampling and determination of moisture content using the oven-dry method 2016-03-16

(e) CEN/TS 17045:2020 (WI=00366017) Materials obtained from end-of-life tyres - Quality criteria for the selection of whole tyres, for recovery and recycling processes 2020-10-07 • CEN/TS 17188:2018 (WI=00366003) Materials obtained from end of life tyres (WASTE TYRE) - Sampling method for granulates and powders stored in big-bags 2018-06-13

(f) CEN/TS 17189:2018 (WI=00366011) Materials obtained from end of life tyres (WASTE TYRE) - Determination of the true density of granulates - Method based on water pycnometry 2018-06-13 End of Life Tyre Rubber: Assessment of Waste Framework Directive End-of-Waste Criteria Project number: 60664059 Prepared for: European Recycling Industries' Confederation & European Tyre and Rubber Manufacturers Association AECOM 33

2. Transboundary movement requirement

104. 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 does not have the technical capacity and the necessary facilities, capacity or suitable disposal sites in order 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 provided those criteria do not differ from the objectives of this Convention.

105. 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.[57]

[58]

106. 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. This is to be done within 90 days of the importing country's notification to the country of export and the secretariat, or within another period of time on which the countries involved agree (Article 8). In the case of illegal traffic (as defined in Article 9, paragraph 1), as the result of conduct on the part of the exporter or generator, 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. (as per Article 9, paragraph 2). For further information, see the Guidance on the implementation of the Basel Convention provisions dealing with illegal traffic, adopted by COP13 in 2017 (UNEP, 2017).

107. 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 agreement or arrangement exists, as required by Article 11 of the Convention.

(g) CEN/TS 17307:2019 (WI=00366009) Material derived from End-of-Life tyres - Granulates and powders - elastomers identification: Gas-chromatography and mass-spectrometric detection of pyrolysis products in solution 2019-03-27

(h) CEN/TS 17308:2019 (WI=00366013) Materials produced from end of life tyres - Steel wire - Determination of the non-metallic content 2019-04-03 • CEN/TS 17510:2020 (WI=00366014) Materials obtained from end-of-life tyres - Determination of the specific surface area of powders - Method based on krypton adsorption 2020-10-07

[57] 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.

[58]

3. Specifications for containers, equipment, bulk containers and storage sites containing waste pneumatic tyres

108. To meet the requirements of ESM and obligations clauses in the Basel ~~and Stockholm Conventions~~ (for example, ~~Basel Convention~~ Article 4, paragraph 8), Parties may need to enact specific legislation that describes the types of containers and storage areas that are acceptable for particular waste pneumatic tyres streams.

109. Parties should ensure that containers that may be transported to another country meet international standards such as those established by the International Air Transport Association (IATA), the International Maritime Organization (IMO) and the International Organization for Standardization (ISO).

C. [Management approaches to used and waste pneumatic tyres][Waste Minimisation and Prevention]

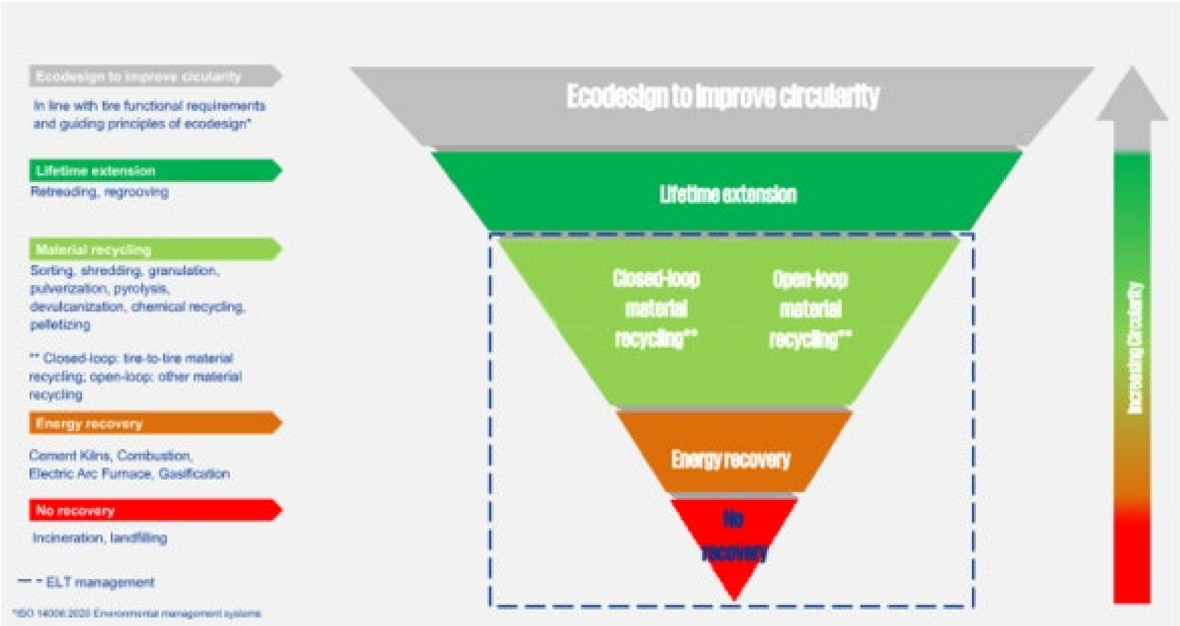
110. Although tyres are consumer goods that are currently essential to any country's economy, inappropriate disposal can affect the environment and human health. As waste generation is unavoidable, it is essential that sound management systems be implemented to minimize waste generation while maximizing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

It is important to move toward a system to reduce and eventually eliminate waste and manage raw material scarcity through the continual use of resources as part of a circular economy. The circular economy is an economic model that is regenerative by design. The goal is to retain the value of the circulating resources, products, parts and materials by creating a system with innovative business models that allow for renewability, long life, optimal (re)use, refurbishment, remanufacturing, recycling and biodegradation. By applying these principles, organizations can collaborate to design out waste, increase resource productivity and maintain resource use within planetary boundaries. For ELT, this involves using, reusing, treating as an abundant and valuable resource and managing them sustainably, together with identifying substitutes for inputs to further the sustainable supply of materials and products. It has been demonstrated at regional and national level that successful ELT management systems can be achieved progressively through the purposeful development of the right conditions. Policies and initiatives that communicate the environmental and socioeconomic benefits of circularity and use of an appropriate waste management hierarchy can foster high ELT recovery rates, and drive the development of recovery methods and ELT products and applications.

1. General considerations

111. [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 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 and to promote circular flows of materials in the economy.]

[Figure III. New,
used and waste tyre management hierarchy]



112. 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 treatment and 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 or thermolysis;

(g) Gasification

(h) Advanced chemical processing

(i) Co-processing;

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

113. The above categories enable the reuse of materials and or energy resulting from treatment processes in the production of new products. As such they contribute to a transition to a circular economy by keeping materials in use for as long as possible. [All other existing processes not mentioned above for treating and disposing of used and waste pneumatic tyres could generate negative environmental impacts and are therefore not considered to be environmentally sound].

2.

2. Policy instruments and measures on waste prevention and minimisation.s

114. Policy instruments 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) Extended producer's responsibility

115. EPR is 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. An EPR policy is characterised by:

- the shifting of responsibility (physically and/or economically; fully or partially) upstream toward the producer and away from municipalities; and
- the provision of incentives to producers to take into account environmental considerations when designing their products.
- While other policy instruments tend to target a single point in the chain, EPR seeks to integrate signals related to the environmental characteristics of products and production processes throughout the product chain.

.There is no "one-size-fits-all" solution. The EPR instrument(s) that is/are the most appropriate to a specific region/country, taking into consideration market conditions, national capabilities and circumstances should be selected. A country has full control of what is covered in EPR and how it will be implemented including how to define the producer. EPR systems could be mandatory or voluntary and be applied at a national level or at a sub-national level (e.g., regional, local or community level) in order to develop participatory initiatives and solutions

116. "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.

117. 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.

118. Environmental authorities should develop regulatory frameworks setting out the responsibilities of relevant stakeholders, components of EPR programmes, and 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.

119. Tyres are in ~~most developing economies~~ many industrialized countries under relevant EPR schemes. In the EU, Member States should establish EPR schemes for tyres manufactures or producers or importers to ensure that they contribute to the cost of waste collection, transport, and treatment of the waste.

120. Components of effective EPR programs related to tyres can include:

(a) Clear definitions of products covered;

(b) Mandatory compliance with legally binding requirements such as recycling and/or treatment quotas;

(c) Effective enforcement provisions including dissuasive fines for non-compliance and the ability for public oversight;

(d) Responsibility and rights with producers furthest up the chain that is under the jurisdiction of the government (this may be the manufacturer, importer, distributor, brand owner, etc.), as the entity that can have the most influence on product design;

(e) Protection for existing informal waste collection workers;

(f) Public education program;

(g) Publicly accessible reporting and data collection;

(h) Financial responsibility borne by producers.

121. Further guidance on EPR is available in the practical manual on extended producer responsibility adopted by decision BC-14/3, in “Extended Producer Responsibility - Guidance for efficient waste management” (OECD, 2016) and in “Development of Guidance on Extended Producer Responsibility (EPR)” (European Commission, 2014)

(b) Tax-based system

122. 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.

123. 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

124. 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.

EPR	Tax-based system	Free-market system
Europe (Belgium, Bulgaria, Czech Republic, Estonia, Finland, France, Greece, Hungary, Italy, Ireland, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Romania, Spain, Slovakia, Slovenia, Sweden), Turkey, Lituania	**Europe** (Croatia, Denmark, Latvia, Slovakia)	**Europe** (Austria, Germany, , Switzerland, United Kingdom)
Brazil, Chile Colombia, Peru	**Canada (in the provinces), United States** (most states)	**United States** (some states)
Canada (some provinces), Israel, Georgia South Africa	Oman	**Australia**

[D. Waste prevention and minimization]

125. The Basel Convention affirms that reducing the generation of hazardous wastes and other wastes to a minimum in terms of quantity and/or hazard potential is the most effective way of protecting human health and the environment from the dangers posed by such wastes. The prevention and minimization of waste pneumatic tyres are the first and second most important steps in the waste management hierarchy. One of the multiple benefits of waste prevention and minimization is the reduction in the release of waste pneumatic tyres into the terrestrial and marine environments. In Article 4, paragraph 2, the Basel Convention calls on Parties to “ensure that the generation of hazardous wastes and other wastes is reduced to a minimum” so that the need for waste management is reduced, enabling resources to be used more efficiently.

126. According to the framework for the ESM of hazardous wastes and other wastes, the need to manage wastes and/or the risks and costs associated waste management can be reduced by not generating wastes and by ensuring that generated wastes are less hazardous (UNEP, 2013).

127. The Basel Convention ESM framework for the ESM of hazardous wastes and other wastes states that “companies that generate wastes (waste generators) are responsible for ensuring the implementation of best available techniques (BAT) and best environmental practices (BEP) when undertaking activities that generate wastes”. In doing so, they act to minimize the wastes generated by ensuring research, investment in design, innovation and development of new products and processes that use less resources and energy and that reduce, substitute or eliminate the use of hazardous materials (UNEP, 2013).

128. Waste management efforts require multi-stakeholder involvement in the development of waste management plans with a strong emphasis on prevention and minimization, in partnership with waste generators, waste /collectors/processors/ recyclers and civil society.

129. A practical manual on waste prevention, as part of the set of practical manuals for the promotion of the environmentally sound management of wastes (UNEP, 2017c), provides stakeholders with general guidance on waste prevention principles, strategies and possible measures and tools. The Guidance to assist Parties in developing efficient strategies for achieving the prevention and minimization of the generation of hazardous wastes and other wastes and their disposal (UNEP 2017d) identifies elements of a waste prevention and minimization programme that apply also to waste pneumatic tyres.

130. Waste management efforts require multi-stakeholder involvement in the development of waste management plans with a strong emphasis on prevention and minimization, in partnership with waste generators, significant downstream industrial users and civil society.

131. Waste pneumatic tyres prevention and minimization should be addressed in a life-cycle perspective approach including measures and procedures in: product redesign to ensure that hazardous substances are avoided; to increase durability, reusability and recyclability of tyres, and to increase sourcing from recycled or renewable feedstock including the incorporation of recycled powder from waste tyre. The choices made at the design stage will also influence the sorting and recycling process and the options available for recycling.

It is important to note that applying ecodesign principles is a means to ensure that the functional features, including regulatory requirements, of a tyre are met while reducing the environmental impact over the entire life cycle. In addition to the design goals cited above, other environmental objectives include energy efficiency, noise reduction, abrasion reduction to reduce TRWP, and others. The design phase requires an optimization of all the desired objectives together. Focusing on certain environmental objectives must be done with caution to avoid compromising key tyre performances, notably those ensuring safety.

132. [Waste prevention or reduction involves both upstream alterations in product design, including use of alternative materials or technologies, as well as alterations in consumer habits. In Europe, product design has focused more on energy efficiency and less on material recyclability, durability, or reparability (European Commission, 2018), yet eco-design determines almost 80 percent of a product's environmental impact (European Commission, 2012). Design strategies that emphasize recyclability, durability or reparability serve two useful objectives – the process produces less waste and by using constituents that are less hazardous, generates waste that is less hazardous.

133. The first step in eco-design is to specify the product functions that are required, including those prescribed by as a condition to putting the tyre on the market. The next steps are to determine the relevant environmental parameters, and then set the environmental improvement objectives. Among these objectives, the following outcomes should be considered holistically at the design stage:

(a) design for optimal resource use e.g., optimize use of tyre in kilometers versus volume of materials required (km/T);

(b) design for environmentally sound use, e.g., extend the lifetime of tires through ease of maintenance (tyre pressure, mounting geometry) and repairability (regrooving, retreading);

(c) design for recycling, e.g., avoiding materials or components that are not easily recyclable;

(d) design for reduced contamination at end of life..

134. Businesses, including manufactures, suppliers and retailers should implement product design communicating information through claims and labels, e.g. for clear and well-designed recyclability labels. Principles such as reliability, relevance, clarity, transparency and accessibility should serve as the main guiding principles of claims and labels (UNEP, 2020d).]

Local authorities should promote waste prevention-based community building through communication where local commerce and industries, as well as consumers, are visible.

E. Collection, transportation and storage

135. Collecting, transporting and storing waste tyres are important phases in the management process and to prevent abandonment or mismanagement of waste tyres. Collecting waste tyres requires logistics and planning, taking account of the diversity of points at which these waste 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.

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

137. Where possible, a pre-cut should be carried out during collection to improve the weight/volume ratio to reduce transportation costs. Shred tyres can be easily transported, so the method of transport can be optimized (weight ratios: 0.5t/m3); the same transport capacity would carry a far smaller quantity of whole tyres (the weight ratio is three times lower at 0.15t/m3). This has a direct impact on transportation needs and therefore on costs.

138. Transporting waste 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.

139. Since collection is a logistical process, optimization should be considered on a cost and environmental basis. Various types of optimizations 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.

140. 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.

141. Sorting is necessary to separate waste tyres that can be retreaded from those that can be used for other purposes,. 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.

142. 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).

143. Stockpiled tyres can present a potential fire hazard and strict conditions must be applied to their storage to minimise the risk of fire danger and to keep communities safe.

Once alight, rubber tyres are extremely difficult to extinguish, generating a large amount of heat and a large volume of smoke.

144. 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.

145. The following requirements must be taken into account when choosing and operating a site for storing tyres:[59]

(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);

[59] MHW (July 2004).

(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).

146. 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.[60]

147. Tyre storage should be undertaken only when necessary and for the shortest time possible.

Table 8.
Best practices for temporary storage of tyres (operations D15 or R13)

Criteria	IAFC, RMA and NFPA guidelines	Specialist *[61]
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

[60] Ibid.

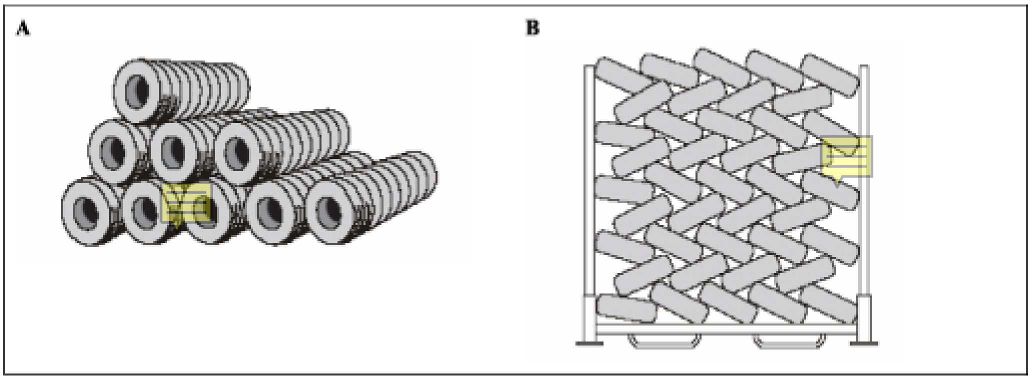
[61] Specialist: Michael Playdon, Columbus McKinnon, February 2004. See bibliography for more information.

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
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 9.
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 treatment and disposal

148. The methods described in the present guidelines illustrate the most common environmentally sound treatment and disposal options and applications. According to the waste management hierarchy, prevention, minimization, reuse and recycling should be prioritized over other recovery operations and final disposal operations. For pursuing recycling and recovery of waste pneumatic tyres, the guidance to assist parties in developing efficient strategies for achieving recycling and recovery of hazardous wastes and other wastes (UNEP, 2019c) may be useful. Table 11 presents some benefits and disadvantages of environmentally sound disposal technologies for waste tyres, while Table 12 presents problems related to environmentally sound treatment and disposal of waste tyres together with ways of preventing and controlling them.

[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.]

Waste pneumatic tyres may be retreaded for further use or can be recovered by being cut, shredded or ground into ready-to-use materials or secondary raw materials for numerous applications:

- Open-loop applications: molded objects (e.g., pieces for making furniture, footwear, household and office products, transportation and industrial equipment); conveyor belts & matting; safety equipment (e.g., blast mats, buffers); construction materials, roads & surfaces (e.g., rubber-modified asphalt, sports & fitness facilities, drainage & substrate materials)
- Closed-loop applications : new tyres can be made by reincorporating high-grade materials into rubber mixes

, []. They can also be used in the form of tyre-derived fuel for energy recovery which is any processes by which waste tyres, particularly end-of-life tyres, are recovered as tire-derived fuel (TDF) or as an energy input to replace virgin fossil fuels for industrial operations (e.g., cement kilns, papermaking, steelmaking) or for generating electricity.

149.

[Table 10. Benefits and disadvantages of environmentally sound means of recovery]

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 compounc during vulcanization. Odour may also an issue in some areas. The process generates significant wastes. The rubl removed from used tyres before retrea 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; • Absorb impact • To minimize infill dispersion CEN 17519:2020 suggets to fitting containment barriers on a pitch's perimeter fencing, installing decontamination grates and boot cleaning brushes at all player, ensuring all stormwater drains around a pitch have suitable microfilters to capture any infill being carried by surface run-off, and keeping a dedicated maintenance brush within the boundaries of the pitch, so it cannot carry infill into the surrounding environment.	• Risk of increased leaching of zin • Risk of rubber or plastic compon that come into direct as well as prolonged contact or short-term repetitive contact with human ski the oral cavity. • In Europe Europe European Commission as regards syntheti polymer microparticles starting fr 2031, has introduced several restriction options for granular in for use on synthetic sports surfac and a ban was establishedon the placing on the market as substar on suggested their own or, where synthetic polymer microparticles present to confer a sought-after characteristic, in mixtures in a concentration equal to or greater than 0,01 % by weight from 17 October 2031.
	Playgrounds, sports grounds and agrimats and equestrian footing	• Smooth with consistent thickness; • High impact resistance; • Durable; • Will not crack easily; • Available in various colours;	• Risk of increased leaching of zin • Risk of rubber or plastic compon that come into direct as well as prolonged contact or short-term repetitive contact with human ski the oral cavity.
	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;	•

	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 t 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;	• Relatively new product, producer have to persuade the industry of i suitability;
	Indoor safety flooring	• Skid resistant; • High impact resistance; • Durable; • Available in various colours; • Easy maintenance;	• ~~Colours may be limited~~; • Limited market;
	Shipping container liners	• Possible use with other packaging problems;	• As a result of damaged packagin containers, waste tyres leak out c containers. In addition, occasiona containers are lost at sea becaus they fall overboard or because a s sinks.
	Conveyor bwaste tyres	• Possible use as conveyor bwaste tyre at supermarket checkouts;	• Cannot be used where the bwast tyre is subject to major stresses, s 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;	•

	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; • ;	• Limited industrial production; •
	Floor tiles	• Resilient; • Skid resistant; • High impact; • Easy maintenance; • Recyclable;	• Limited industrial production; •
	Activated carbon (carbon black)	• Preserves virgin material; •	• ; • Very energy intensive; • Low-grade activated carbon; • ~~Still at the research stage;~~
	Livestock mattresses	• ~~Long life span;~~ • ~~Easy to disinfect;~~ • ~~Reusable;~~ •	• ~~Market potential unknown;~~ •
Civil engineering	Landfill engineering	• ~~Lightweight, low-density fill material;~~ • ~~Good load-bearing capacity;~~ • ~~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;~~
	~~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 not maintained; • Compaction difficult (need to use more than 10-ton roller, six pass 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 anchor to prevent mobility under flood conditions; • Tyres can trap debris, (need maintenance); • Anchors can shift over time due 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; •
Pyrolysis also called thermolysis	Pyrolysis Oil (TPO) Pyrolysis Gas Recovered carbon black Ash/Char	• 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 proc contains metals and other waste which, for the moment, are depo in abandoned mines thus posing environmental problem;
Gasification	Syngas Char	• Reutilizes the byproducts of Gasification (char and Syngas) • Aligns with principles of a circular economy by maximizing recource use and minimizing waste	• Very limited existing sites • Cost-intensive further processing of output materials is necessary in order to be able to use th as new raw materials (e.g. rCB or petrochemica Industry) •

Advanced Chemical Processing or Advanced Chemical Recycling	Various Products out of the petrochemical Industry like Chemicals, fuels or petrochemical raw materials	• Advanced Chemical Recycling provides increases efficiency in breaking down complex materials like Syngas or Pyrolysis-oil and enabling the recovery of high-quality raw materials. Which reduces the dependency on fossil resources.	• High initial costs • Cost-intensive processing of input materials is necessary i order to be able to use them new raw materials • Limited existing sites
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 th 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 t 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) Valentini and Pegoretti (2022)[62]

[62] https://www.sciencedirect.com/science/article/pii/S2542504822000392

Table 11.
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;~~	• ~~Intervention from federal and/or local governments is essential for effective rubber waste management, and many countries have implemented various policies and regulations on issues related to waste management.~~
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; Limitquantity used;
Pyrolysis also called thermolysis	• Air emissions; • Hazardous residues; • Liquid effluents;	• Air and water treatment systems; Technologies for ESM of hazardous wastes;
Gasification	• Air emissions; • Hazardous residues; • Liquid effluents;	• Air and water treatment systems; Technologies for ESM of hazardous wastes;
Co-incineration	• Risk of air emissions above legal limits;	• 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. • Monitoring and stabilization of critical process parameters
Advanced Chemical Processing or Advanced Chemical Recycling	• Potential release of harmful emissions during processing • Regulatory frameworks are patchy. A uniform recognition as a recycling method is necessary with a clearer definition of the	• Air and water treatment systems; Technologies for ESM of hazardous wastes; • Intervention from federal and/or local governments • Monitoring and stabilization of critical process parameters

	end of waste status	
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.
- 2. All the applications mentioned above need raw materials obtained from waste 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 waste 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.

150. The most widespread recovery techniques for waste tyres are recycling and energy recovery. Material recovery processes are covered under R3 (Annex IV Section B). There are also techniques for the disposal of tyres not leading to recovery. Use as fuel, and coprocessing are recovery operation covered under R1 and R5 codes (Annex IV Section B).

151. It is important to keep in mind that the regulations for waste and/or waste tyre management and the economic context will in most cases determine the various means used to manage wastetyres.

152. In the current worldwide energy situation, waste tyres may 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.

153. The use of materials produced from tyres, such as rubber shred, granulates, pellets or powder, is growing and accounts for a large percentage of the management of waste 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.

154. 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.

155. 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.

156. Whereas first-generation recycling facilities have often been criticized for generating dust and noise and a high proportion of waste material, tfacilities using best available technology and best available practices 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.

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

Table 12.
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

158. 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.

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

160. [Retreading may take place in the prevention phase as a re-use measure or in the waste recovery/disposal phase where used tyres that have been discarded may undergo retreading, thus increasing the useful life of tyres through retreading in both phases.]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.

161. 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.

162. 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.[64]

163. 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.

164. 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.

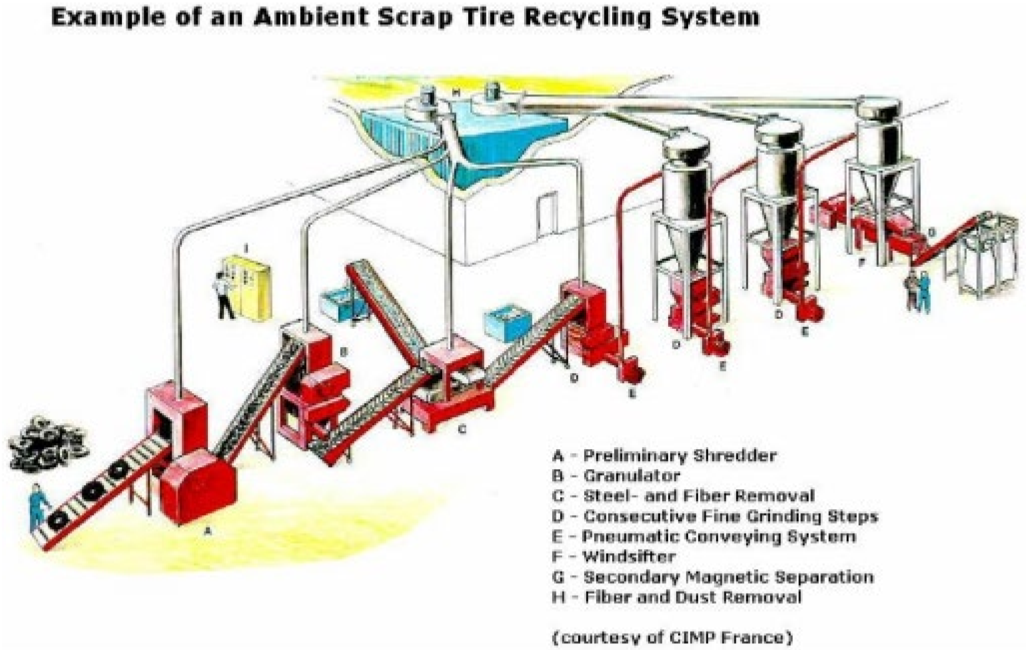
2. Mechanical/physical recyling (R3)

166. 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.

167. 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.

[64] A National Approach to Waste tyres (2001).

Figure V
Schematic of an ambient waste tyre processing plant



Source: Reschner (2006).

168. 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).

Table 13 - The summary of the steps involved in ambient rubber separation process together with required equipment

Process	Machine	Description
Bed wire extraction	Bead extractor	Bead wires are drawn from the tyre through a mechanical hook
Rough shredding	Roller shredder	Tyres are roughly shredded through shearing in a roller shredder
Granulation	Roller shredder	Tyre chips are further downsized using roller shredders
Steel wire extraction	Magnetic separator	Liberated steel wired are collected via an electromagnet and conveyor
Milling/pulverisation	Cracker mill/ cutter	Steel free rubber granulates are further downsized in a cracker mill or pulverisation mill
Textile/Fibre Separation	Vibrating screen/ airflow separator	Rubber crumb is screened and separated to remove textiles using vibration and airflow

Source: https://www.sciencedirect.com/science/article/pii/S2772397622000752

169. 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 remwaste tyreing in steel plants. All rubber granulate output can be produced in sizes below 10 mesh (2.0 mm).

170. 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.

171. 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.

172. The tyre recycling material recovery process called “cryogenic” is where 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, generating rubber granulate and powder, including micronized rubber powder. 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 which can be used in multiple applications.

173. The cryogenic process is illustrated in figure VI.

Figure VI
Cryogenic waste tyre recycling

Source: Reschner (2006).

174. 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.

175. 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).

176. 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.

177. 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~~ rubber materials recovered from waste tyres

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][Physico chemical treatment (R3)]

178. 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.

179. Devulcanization is a chemical process by which bonds of vulcanized rubber are broken without shortening the carbon chains. Devulcanization is a recovery method for waste tyre. In particular, 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.[65]

180. The chemical devulcanization process is a batch process in which reduced particles 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.

181. 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.

182. 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[66]. ~~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.~~[67]

[65] Calrecovery Inc. (2004).

[66] https://www.sciencedirect.com/science/article/abs/pii/S016523701200232X

[67] Gert-Jan van der Have (2008).

183. 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.

184. 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 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.

[4. Industrial and consumer products

185. 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 bwaste tyres, 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

186. 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.

187. 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.

188. 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).

189. Proposed new 241: European Committee for Standardisation (CEN), have developed a Technical Report describing the procedures that should be used to control infill migration. These include: fitting containment barriers on a pitch's perimeter fencing, installing decontamination grates and boot cleaning brushes at all player, ensuring all stormwater drains around a pitch have suitable microfilters to capture any infill being carried by surface run-off, and keeping a dedicated maintenance brush within the boundaries of the pitch, so it cannot carry infill into the surrounding environment.

(b) Playgrounds and sports grounds

190. 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.

191. Based on the presence of PAHs in tyres and on the fact that these PAHs are also present in granules from the treatment of waste tyre, ECHA has evaluated the risks to human health from

substances found in recycled rubber granules that are used as an infill material in synthetic turf. In particular, ECHA has:

- investigated the risks to the general population, such as children playing on synthetic sports fields, adults playing professional sports, and workers installing or maintaining the fields.

- considered exposure to rubber granules by skin contact, ingestion and inhalation of substances evaporating from the granules, as well as of dust formed by granules themselves.

192. ECHA establishes a limit of 20 mg/kg[68] for the sum of REACH-8 PAHs established for rubber granules and mulches in loose form for use in playgrounds. ECHA considers also that such limit helps to significantly reduce children's exposure to PAHs by preventing the use of rubber granules and mulches with high PAH content in the EU[69].

193. In Europe European Commission with REGULATION (EU) 2023/2055 of 25 September 2023 amending Annex XVII to Regulation (EC) No 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) as regards synthetic polymer microparticles starting from 2031, has introduced several restriction options for granular infill for use on synthetic sports surfaces and a ban was establishedon the placing on the market as substances on suggested their own or, where the synthetic polymer microparticles are present to confer a sought-after characteristic, in mixtures in a concentration equal to or greater than 0,01 % by weight from 17 October 2031.

194. This restriction is based onthe presence of tiny fragments of synthetic or chemically modified natural polymers, which are insoluble in water, degrade very slowly and can easily be ingested by living organisms, raises concerns about their general impact on the environment and, potentially, on human health. Improper management of sports fields with polymeric infill and playground with loose application granulates can lead to the spread of rubber granulates to the vicinity of the fields and playgrounds. Therefore it is important to establish proper management protocols and mitigation measures to keep the rubber granulates on the fields. Multiple field monitoring programs have proven the effectiveness of these risk management methods.

(c) Applications in rubber-modified concrete

195. 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.

196. 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 bwaste tyres;

(f) Car mats;

(g) Footwear;

(h) Carpet underlay;

(i) Roof tiles;

(j) Flooring;

(k) Activated carbon (carbon black);

[68] 20 mg/kg is not a risk-based limit since a dose without a theoretical cancer risk cannot be derived for these substances. As a general principal exposure should be lowered. A value of 20 mg/kg is a practical-based limit equating to an approximate reduction of 95% in what is permitted to give a theoretical risk of 2.9 x 10-5 for workers and 2.8 x 10-6 for the consumers " - https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e181d5746d

[69] https://echa.europa.eu/registry-of-restriction-intentions/-/dislist/details/0b0236e181d5746d

(l) Livestock mattresses;

(m) Thermoplastic elastomers.

(d) Road applications

197. Granulated materials obtained from waste tyres have been used in the development of rubber-modified asphalt in the United States, Europe, South Africa, Australia, Asia and Brazil. There are two main processes for producing rubber asphalt: the wet process and the dry process.[70]

198. 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.

199. 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.

200. 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.[71] 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.[72] Today, rubber asphalt applications account for the disposal of 2 per cent of waste tyre .[73]

201. 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.[74]

202. 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.[75] 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.

203. Studies haave 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 categories such as potential for global warming, acidification and cumulative energy demand (DTC & IFEU 2008).[76]

204. 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.

205. ASTM D6114 covers asphalt-rubber binder, consisting of a blend of paving grade asphalt cements, ground recycled tire (that is, vulcanized) rubber and other additives, as needed, for use as binder in pavement construction. The rubber shall be blended and interacted in the hot asphalt cement

[70] Caltrans (January 2003).

[71] Intermodal Surface Transportation Efficiency (1995).

[72] United States Department of Transportation, Federal Highway Administration, Crumb Rubber Modifier.

[73] Sheerin, John (2004).

[74] FABES (2006).

[75] National Institute for Occupational Safety and Health (2001).

[76] DTC and IFEU (2008).

sufficiently to cause swelling of the rubber particles prior to use. Tests shall be performed to conform with the physical requirements of the asphalt-rubber binder, in accordance with the following test methods: apparent viscosity; modified test method; penetration; softening point; resilience; flash point; thin-film oven test residue; and penetration retention

206. According to ASTM D6114, to produce Asphalt-Rubber, the rubber should have the following characteristics:

(a) Less than 0.75% moisture and free flowing.

(b) Specific gravity of 1.15 ± 0.05. No visible nonferrous metal particles.

(c) No more than 0.01% ferrous metal particles by weight.

(d) Fibre content shall not exceed 0.5% by weight (for hot mix binder applications).

(e) Recommends all rubber particles pass the No. 8 (2.36 mm) sieve.

(f) (Note that Rubber gradation may affect the physical properties and performance of Bitumen Rubber hot mix).]

5. Civil engineering

207. Civil engineering and backfilling is the recovery route where waste tyre are recovered through civil engineering applications (water retention and infiltration basins, supporting walls, etc.) and through landfilling of mining activities (tires that are shredded or chipped and mixed in with other geological materials to reclaim sites that have been mined out for example).

208. 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.

209. 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.

210. 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.

211. 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.

212. 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) Special engineered landfill

213. 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) Waste tyre bales in landfill haul roads.

214. 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

215. 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 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

216. 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

217. 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

218. 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.

219. Using shredded waste tyres as a lightweight fill material for road construction has proved to be another beneficial use of waste tyres, e.g., in logging roads through areas with weak soils.[77] 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.[78]

6. Thermal treatment: Pyrolysis

220. Pyrolysis or thermolysis is a process in which chemical decomposition is induced in organic materials by heat in the absence or near-absence of oxygen under pressure or vacuum and operating temperatures above 500°C. ELT materials are decomposed into oil, gas, steel, ash/char and recovered carbon black in different proportions depending on operating conditions. Pyrolysis is one among other chemical processing methods, e.g., carbonisation, gasification and thermolysis, that recover materials and alternative fuels from ELT which can be used as substitutes for those produced from virgin fossil fuel feedstock. It is a therefore both a material and energy recovery method. Thermolysis is an interchangeable term for this process.

221. 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.

222. Pyrolysis gas is the gaseous fraction of the pyrolysis process. It features heating value around 46 MJ/kg that is comparable to natural gas (depending on the pyrolysis process). The syngas obtained

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

[78] Reid, J. M. and M. G. Winter (2004).

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.

223. Tyre pyrolysis char is the solid fraction of the pyrolysis process. The char is typically a carbon-rich fraction but its carbon content is depending on the type of feedstock. . However, modern techniques may produce a recovered carbon black comparable to fossil based carbon black. Recovered carbon black is essentially recycled carbon black out of the pyrolysis char, and is a valuable material commonly used as a reinforcing filler and a substitution for fossil based carbon black in the production of rubber products, plastics, and other industrial applications.

Tyre Pyrolysis oil (TPO), is the liquid fraction obtained through the pyrolysis process. Pyrolysis oil has potential applications as a fuel, though its composition can vary based on the feedstock and specific pyrolysis conditions and can be also used as an input material for chemical recycling, to produce new raw materials.

224. 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.[79]

225. 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.

226. Like with any other process, there might be risks associated to the conduction of a poor pyrolysis process. Material such as steel recovered from whole tyre and/or shred pyrolysis may be contaminated with carbon 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.

227. [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.

228. 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

[80]

229. The term "co-processing" is the use of suitable waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution, Infact, it 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. .[81] 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. [82]

230. 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 characteristics of the tyres and kiln used.

[79] Karpetsky, Timothy (2001).

[80]

[81] Holcim, GTZ (2006).

[82] https://www.basel.int/Portals/4/Basel%20Convention/docs/pub/techguid/cement/tg-cement-e.pdf

~~231. 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.~~

~~232. 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.~~

233. 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.

234. 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.

235. 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).

236. 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;

(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.

237. According to the German cement industry, the heating value of used tyres for co-incineration is 26 MJ/kg (VDZ 2008).[83] This value is confirmed in UBA (2006),[84] where the average heating value for used tyres as secondary fuel is 25.83 MJ/kg.

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

Table 16.
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.

239. 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.

(a) Quality requirements

240. 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.

241. 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

242. 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.

243. 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.

244. 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

83 VDZ (2008).
84 UBA (2006).

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.[85] 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".[86]

245. 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.[87]

246. In terms of emissions formation, proponents of tyre-derived 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

247. Process control and monitoring is essential to keep emissions low (under reference parameters or below quality standards).. 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.

248. 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.

249. 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)].

250. 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.

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

[85] Foundation for Scientific and Industrial Research (2006).

[86] Canadian Council of Ministers of the Environment (2004).

[87] European Comission (May 2010).

(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.[88]

252. 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-dioxins and polychlorinated dibenzofurans and metals, can be found in the reference document on the best available techniques in the cement industry.[89] This solution[90] 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) .

253. 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.

254. 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.[91]

8. Co-incineration in plants for electric power generation

255. According to Menezes,[92] 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.

256. 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.

257. 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

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

[89] European Commission (May 2010).

[90] Section V.B. Cement Kilns firing hazardous wastes" BAT/BET Guidelines under Stockhom Convention and the "Technical guidelines on the environmentally sound co-processing of hazardous wastes in cement kilns" adopted by Decision BC-10/8

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

[92] Menezes (2006).

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.

258. 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.

259. 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).

G. Health and safety

260. Both the supplier and receiver of the materials should ensure that the following information is available, when required:

(a) The identity, quality and form of the waste tyres;

(b) The safe handling instructions appropriate to the waste tyres;

(c) The protective clothing that should be worn by employees, including eye and ear protection, gloves, protective footwear, filter masks and hard hats, depending on the processing to which the waste tyres is subjected;

(d) The safe storage of the compacted waste tyres including mechanical handling equipment, stack heights/stability and stack spacing;

(e) Fire prevention, firefighting, fire extinguishers, emissions from burning waste tyres, advice to fire fighters, means of dealing with fire residues.

261. To improve the knowledge regarding possible risk due to contamination, the origin of the waste and information on how the waste is generated will help improve recycling and reduce risk to employees. Waste operators should have access to sufficient information on relevant hazardous substances (additives etc.) used at the production step of the tyres.

262. The following rules should apply in the workplace:

(a) Smoking should be forbidden in the waste tyres storage and disposal areas and such areas should be protected by secure fencing;

(b) Ready access to all parts of storage areas should be maintained by well-organised and supervised stacking patterns in order to ensure efficient working conditions, easy emergency escape routes for workers and ready access for emergency services vehicles;

(c) Suitable extinguishers should only be readily available in storage areas, but staff should attempt to extinguish fires in their very earliest stages.

263. 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..

264. 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.

1. Fire and safety

265. In the event of a fire (at any industrial operation):

(a) All staff should evacuate the premises immediately and assemble at recognised points and be counted;

(b) The emergency services should be summoned immediately and should be reminded:

  a. Of the speed at which fire can spread in burning tyres;

  b. That burning tyres may form a mobile stream of burning material which can rapidly transfer the fire to other areas and can also block drains of the need for self-contained breathing apparatus when entering a building in which any material is burning.

266. For example, good practice guidance managing fire safety during the reception, treatment and storage of solid combustible wastes is provides by the Waste Industry Safety and Health (WISH) Forum on reducing fire risks at waste management sites (WISH, 2020).

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.

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

Fire prevention measure should be put in place when storing tyres to:

(a) ensure risk of fire is prevented

(b) if a fire does occur, early detection is in place

(c) fire extinguishing measures are installed to tackle any fire and stop it from spreading

fire-fighting water and foams are recirculated where possible and contained

2. Smoke and toxic gases

267. The major cause of deaths in accidental fires is through the inhalation of carbon monoxide and smoke which should be prevented (Fardell, 1993). Fire brigades usually regard the smoke and fumes from any accidental fire as toxic and employ self-contained breathing apparatus when entering a burning building whatever material are involved.

268. It should be considered that burning tyres emit acid gases but are much more difficult to ignite than other plastics and they burn very slowly. It should also be considered that hydrogen fluoride from burning fluorinated polymers is acutely poisonous, toxic and ecotoxic.

269. Toxic gases emitted during thermal degradation are harmful on their own but can also multiply each other´s harms. Such is the case for carbon monoxide and hydrogen cyanide, which when emitted together from polyurethane insulation foam (a thermoset plastic) significantly increase the risk of cardiac arrest and cancer, hazards well-known to firefighters (Drager Safety AG & Co, N/A).

270. The soot from burning materials, natural and man-made, contains small concentrations of more toxic materials and so it should be handled with care using appropriate protective clothing. Toxic materials are firmly bonded onto the surface of soot particles and so they are not very biologically active.

H. Emergency response

271. Emergency response plans should be in place for waste tyres in production, use, storage and transport or at disposal sites. The principal elements of an emergency response include:

(a) Identifying all potential hazards, risks and accidents;

(b) Identifying relevant local and national legislation governing emergency response plans;

(c) Planning for anticipated emergency situations and possible responses to them;

(d) Maintaining a complete up-to-date inventory of the waste pneumatic tyres on site;

(e) Training personnel in response activities, including simulated response exercises, and first aid;

(f) Maintaining mobile spill response capabilities or retaining the services of a specialized firm for spill response;

(g) Installing mitigation measures such as fire suppression systems, spill containment equipment, fire-fighting water containment, spill and fire alarms, and firewalls;

(h) Installing emergency communication systems, including signs indicating emergency exits, telephone numbers, alarm locations and response instructions;

(i) Installing and maintaining emergency response kits containing sorbents, personal protective equipment, portable fire extinguishers and first aid supplies;

(j) Integrating facility plans with local, regional, national and global emergency plans, if appropriate;

(k) Regularly testing emergency response equipment and reviewing emergency response plans.

272. Emergency response plans should be prepared jointly by interdisciplinary teams that include emergency response, medical, chemical and technical personnel and labor and management representatives. When applicable, representatives of potentially impacted communities should also be included.

I. Awareness and participation

273. Public participation is a core principle of the 1999 Basel Declaration on Environmentally Sound Management and many other international agreements. It is essential that the public and all stakeholder groups have a chance to participate in the development of policy related to waste pneumatic tyres, the planning of programmes, the development of legislation, the review of documents and data, and decision making on local issues related to waste pneumatic tyre. Paragraphs 6 (g) and (h) of the Basel Declaration reflect an agreement to enhance and strengthen efforts and cooperation to achieve ESM with regard to the enhancement of information exchange, education and awareness-raising in all sectors of society, and cooperation and partnership at all levels between countries, public authorities, international organizations, industry, non-governmental organizations and academic institutions.

274. Articles 6, 7, 8, and 9 of the UNECE 1998 Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Aarhus Convention) require the parties to conduct fairly specific types of activities regarding public participation in specific government activities, the development of plans, policies and programmes and the development of legislation, and call for access to justice for the public with regard to the environment.

275. Public awareness and attitudes to waste pneumatic tyres can affect the population's willingness to cooperate and participate in adequate waste pneumatic tyres management practices. General environmental awareness and information on health risks due to deficient waste pneumatic tyres management are important factors, which need to be continuously communicated to all sectors of the population.

276. Raising public awareness and promoting public participation is especially critical for separation and collection as important steps for environmental sound management of waste pneumatic tyres.

277. Local authorities should organize awareness raising campaigns/events addressed to business (commercial, beach users, fishermen, etc.) and public (tourists, households, etc.) to make people aware of the importance of ESM of waste tyres in tackling environmental problems such as marine litter, and in improving people's lives. There exists a variety of communication techniques that can be used to address them such as door to door information, leaflets, community meetings, media etc. Communication objectives could (Climate and Clean Coalition, 2013):

(a) Address cultural practices and beliefs;

(b) Emphasize health benefits;

(c) Use simple messages and multiple media types;

(d) Build on existing neighborhood networks;

(e) Emphasize the economic and health benefits of proper waste pneumatic tyres management;

(f) Frame waste pneumatic tyres management activities as a topic of great interest for voters;

(g) Increase visibility and credibility of waste pneumatic tyres management activities (e.g., by issuing uniforms to workers)

(h) Identify instances where city activities support national goals;

(i) Communicate about the national benefits of proper local waste tyre management (e.g., to attract investments) Tailor communication to the audience;

(j) Emphasize the economic benefits to businesses (e.g., better conditions for attracting investments);

(k) Target groups with broad influence (e.g., tourism boards).

278. 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.

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Appendix I

Public health literature

Dengue fever is transmitted by mosquitoes breeding in containers that collect rainwater, particularly used tyres.[93] A single tyre can serve as a breeding site for thousands of mosquitoes in just one summer.[94] 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.[95] 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.[96] 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."[97]

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*."[98]

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."[99]

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.[100] The World Health Organization recognized that dengue was "the most important emerging tropical viral disease" and "a major international public health concern".[101] Its symptoms range from high fever, severe headaches and muscular pain to haemorrhaging, frequently followed by swelling of the

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

[94] Ohio Department of Natural Resources (1986).

[95] Yamaguchi, E. (2000).

[96] Borges, Sonia Marta dos Anjos Alves (2001).

[97] "*Biting Back*", Environmental Health Practitioner (2004).

[98] Kobayashi, M. and others (2002).

[99] Chester, G. Moore and Carl J. Mitchell (1997).

[100] Texeira, Maria da Glória (2005).

[101] World Health Organization (1999).

liver and poor circulation.[102] Dengue hemorrhagic fever has a death rate of from 5 per cent to 15 per cent when left untreated.[103] 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.[104] 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.[105] Cases of hemorrhagic dengue increased 45 times from 2000 until 2002,[106] reaching a peak mortality rate of 4.3 per cent, almost eight times as high as the rate in South-East Asia.[107] Brazil accounted for 70 per cent of reported cases in the Americas from 1998 to 2002.[108] Today, three of the four serotypes of dengue co-circulate in 22 of the 27 states in Brazil,[109] 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,[110] 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),[111] 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, as co-incineration or co-processing in cement kilns.

[102] WHO Dengue Fact Sheet.

[103] Donald Kennedy and Marjorie Lucks (1999).

[104] WHO Dengue Fact Sheet.

[105] Siqueira, João Bosco and others (2005).

[106] Ibid.

[107] Figueiredo, Luiz Tadeu Moraes (1985–2004) (2004).

[108] Siqueira, João Bosco and others (2005).

[109] Ibid.

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

[111] 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 [112]
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[113]	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.

[112] O'Shaughnessy V.O., Garga V.K. (2000).

[113] Riaz A.K., Ahmed S. (2001).

2. General abbreviations used in table: PDWS, United States primary (health) drinking water standard; SDWS, United States secondary (aesthetic) drinking water standards; GWT, groundwater table; GW, groundwater.

As presented in Section I.D.2 (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:[114]

(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),[115] 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.

[114] MWH (July 2004).

[115] Sheehan, P.J. and others (2006).

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)

<table>
<tr><th>Application</th><th>Chemical property</th><th>Limiting values
(µg / l, unless stated)*</th></tr>
<tr><td rowspan="22">- Landfill engineering
- Lightweight fill and soil
- Reinforcement
- Bridge abutments
- Drainage applications
- In-ground barriers
- Noise barriers
- Thermal insulation
- Tyre products and surfacing</td><td>pH</td><td>5.5–9.5</td></tr>
<tr><td>Conductivity</td><td>1000 µs/cm</td></tr>
<tr><td>Carbon Organic Dissolved</td><td>30 mg/l</td></tr>
<tr><td>Ammonia</td><td>0.5 mg/l</td></tr>
<tr><td>Arsenic</td><td>10</td></tr>
<tr><td>Cadmium</td><td>1</td></tr>
<tr><td>Chromium (total)</td><td>50</td></tr>
<tr><td>Lead (total)</td><td>50</td></tr>
<tr><td>Mercury</td><td>1</td></tr>
<tr><td>Selenium</td><td>10</td></tr>
<tr><td>Boron</td><td>2000</td></tr>
<tr><td>Copper</td><td>20</td></tr>
<tr><td>Nickel</td><td>50</td></tr>
<tr><td>Zinc</td><td>500</td></tr>
<tr><td>Cyanide (free)</td><td>50</td></tr>
<tr><td>Sulphate (SO_4)</td><td>150 mg/l</td></tr>
<tr><td>Sulphide</td><td>150</td></tr>
<tr><td>Sulphur (free)</td><td>150</td></tr>
<tr><td>Phenol</td><td>0.5</td></tr>
<tr><td>Iron</td><td>100</td></tr>
<tr><td>Chloride</td><td>200 mg/l</td></tr>
<tr><td>Polycyclic aromatic hydrocarbons</td><td>0.2</td></tr>
<tr><td>- Erosion control (fluvial &</td><td rowspan="2">As above (if necessary)</td><td rowspan="2">As above (if necessary)</td></tr>
<tr><td>- Artificial reefs</td></tr>
</table>

* 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.

		6 days	3.5 million			

Field monitoring of the 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.

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.

Riaz 73 Ibid.

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

75 Ibid.

76 Ibid.

6 days

3.5 million