Tyre Generic Exposure Scenario

Service Life Guidance

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<u>List of Abbreviations</u>

AC	Article Category
CSA	Chemical Safety Assessment
CSR	Chemical Safety Report
DU	Downstream User
ERC	Environmental Release Category
sERC	specific Environmental Release Category
ES	Exposure Scenario

ESD	Emission Scenario Document
GES	Generic Exposure Scenario
M/I	Manufacture/Importer
RAR	Risk Assessment Report
RCR	Risk Characterization Ratio
STP	Sewage Treatment Plant
TGD	Technical Guidance Document
TRA	Targeted Risk Assessment

1.0 Summary

To characterize substance emissions attributable to tyre wear particles (TWP) during the service life of a tyre, the use of regional screening model for TWP within the framework of the default ERCs is recommended. This section describes scenarios for the tyre service life based on an application of the default environmental release categories (ERCs) from the REACH Technical Guidance Document (TGD) as well as refined specific ERCs (sERC). The service life of a tyre is included in the TGD as part of ERC 10B – "Wide dispersive outdoor use of long-life articles and materials with high or intended release." The default ERC 10B assumes that 100% of the regional tonnage of a substance present in an article is directed to air, water and soil, resulting in an emission rate three times higher than the actual usage volume. The recommended refinements to the default ERC include defining a release rate that preserves mass balance, as well as setting realistic release fractions for the regional and local 'standard' town scenario (used for local STP assessment in wide dispersive ERCs).

In accordance with the REACH guidance for articles, substances in TWP are treated as if they were in the molecular form in the initial Tier 1 screening assessment. However, many tread substances are cross-linked in the rubber matrix during vulcanization and characterized by low water solubility. Given oxidation as the primary proposed mechanism for environmental degradation of a TWP, remaining cross-linked chemicals would be also subject to such oxidation, which make their direct release into the environment unlikely. Certain substances are not cross-linked and therefore theoretically could leach from TWP to varying degrees as a function of various parameters.

The European TWP emission rate is estimated based on the 'sales approach' and 'mileage approach' estimates presented in Blok (2005). The real-world end of life loss fraction for tyres of 11.5% paired with distance or sales information is recommended. These calculations predict that the continental Europe TWP emission rate is approximately 400,000 tons per year and that the regional emission rate is approximately 3% of the continental rate, or 11-12,000 tons per year. These estimates are comparable to those presented in the EU Risk Assessment Reports (RARs) for aniline (final), Zn metal (final) and CBS (final). In the REACH TGD, a local sewage treatment plant (STP) scenario is included as part of ERC 10B and other outdoor scenarios. An estimate of per capita annual TWP generation rate for urban areas is recommended to calculate a refined local fraction of the main source required for the local STP scenario. For the sERC, a TWP release fraction of 67% to water and 33% to soil is recommended based on previous studies of zinc removal from roadways by runoff and drift. Parameters for the ERC and sERC are provided in **Table 1**. The list of substances found in tyre tread, the concentration range and transformation rate for each substance can be obtained by request to ETRMA. More details and documentation regarding the service life scenario are provided in the remainder of this document.

In addition to the primary substances used in formulation and processing, chemical transformation products and impurities should also be considered for some substances. The chemicals relevant to tyres most often identified in leaching studies or the EU RARs include cyclohexylamines, benzothiazole compounds, aniline, 6-PPD and its degradation products (OECD 2004; Danish MOE 2008; European Union 2007; European Union 2004).

Table 1: Default ERC and refined sERCs for Tyre Service Life

Parameter	ERC 10B (Table R.16-23)	Refined sERC with Local STP	References
Total continental emission rate of TWP	No default (400000 t/y)	--[a]	Total continental emission rate of TWP based on tyre sales (Blok 2005).
Substance concentration in TWP	See ETRMA Substance List	--	By request to ETRMA.
Substance transformation rate	See ETRMA Substance List	--	By request to ETRMA.
Level of containment	Open	--	--
Type of use in LCS	Inclusion into matrix	--	--
Dispersion of emission sources	Wide dispersive	--	--
Indoor/outdoor	Outdoor	--	--
Release promotion during service life	High	--	--
Amount of substance used as input to emission calculation (regional concentration)	10% (40000 t/y)	3.05% (12200 t/y)	Refinement based on calculated TWP emissions in the Netherlands, with population and land surface area comparable to that of the default REACH region (Blok 2005).
Fraction directed to local source	0.2% (80 t/y)	0.036% (4.4 t/y)	Refinement based on per capita urban TWP generation rate for the Netherlands and standard town population of 10000 occupants (Blok 2005).
Release time in days per year	365	--	--
With STP (regional)	80%	--	--
With STP (local)	Yes	--	--
Default release to air (%)	100%[b]	0%	Research indicates that the TWP content in airborne PM is low and most particles generated settle immediately after release (Cadle and Williams 1978; Pierson and Brachaczek 1974).
Default release to water (%)	100%[b]	67%	Refinement based on 2:1 ratio of removal of roadway Zn by runoff versus drift (Blok 2005).
Default release to soil (%)	100%[b]	33%	Refinement based on 2:1 ratio of removal of roadway Zn by runoff versus drift (Blok 2005).
Dilution for PEC calculation - regional	25 x 10^9 (m^3/year)	--	--
Dilution for PEC calculation – local STP	10 (20000 m^3/day)	--	--

[a]-- indicates no change from ERC.
[b]ERC default assumption of 100% for air, water and soil corresponds to total emission 3 times higher than actual TWP emission rate

2.0 Introduction

Part D of the REACH CSA TGD provides Manufacturers and Importers (M/I) the option of using Environmental Release Categories (ERC) for initial exposure scenario development as well as subsequent refinement of the default parameters in the ERCs based on iteration between the downstream user (DU) and M/I.

The service life of a tyre is defined in Part D and Chapter R.16 as part of ERC 10B – “Wide dispersive outdoor use of long-life articles and materials with high or intended release.” The application of the default ERC is recommend, followed, if necessary, by application of a refined specific ERC (sERC) or alternate approaches on an as needed chemical specific basis. This approach allows transparent identification of the sensitive parameters and provides a framework for additional refinements, if necessary, to demonstrate control of risk.

Higher tier information could include refined chemical specific information such as degradation or hydrolysis rates, a refined toxicity analysis or more precise characterization of market average concentration in the tread. Some refinements to the ERC, such as the fraction of TWP allocated to a region, can be defined generically. In other instances, refinement of chemical specific properties used in the supplier risk assessment, in addition to refinement of the ERC may be necessary. This attachment describes regional scenarios as well as the default local scenario.

3.0 Default ERC

In the REACH CSA TGD, tyres are included in ERC 10B - Wide dispersive outdoor use of long-life articles and materials with high or intended release. Appendix D-5 links articles categories (AC) to ERCs. Rubber products are assigned to AC10-1 (formerly AC15), with ERC differentiation by tyres, flooring, footwear and toys. This scenario addresses substances included into articles with high release rates during the service life. The generic ERCs do not take into account specific chemical or article properties, therefore some ERCs, including ERC 10B, include the assumption that 100% of releases occur to more than one compartment. For ERC 10B, 100% of chemical in the article is assumed to be directed to each of air, soil and water such that total emission rate using the default ERC is 3 times greater than theoretical maximum emission rate.

Other attributes of the default ERC include a default release of 10% of total continental emissions directed to a densely populated region of 20 million and the allocation of 0.2% of regional emissions to water from a local sewage treatment plant (STP). For regional emissions, a fraction of 80% water discharges with an STP is assumed. The EUSES default dilution factors and per capita water usage rate are also used.

For wide dispersive uses, the REACH TGD considers the regional scale to be the most relevant because emissions are widely distributed. However, a generic local release is also required for all ERCs with wide dispersive uses, including ERC 10B. This scenario addresses a local release to waste water. By default in the ECETOC TRA Tier 1 model, sewage sludge is not assumed to be directed to agricultural soil in the environmental model implementing the ERCs. However, all direct emissions to soil are assumed to occur to agricultural soil. This is a conservative assumption for TWP because soils immediately adjacent to the roadway are considered to be part of the technosphere and therefore could reasonably be classified as industrial soils.

4.0 Additional REACH Guidance for Articles

REACH guidance specific to articles is provided in CSA TGD Chapter R.17. Emissions during the service life "are considered to be diffuse emissions that usually cause exposure on a regional scale (R.17.4.1)". The guidance later states that "releases from articles will normally only contribute to regional releases" but that outdoor uses might cause releases to a STP if the storm water system is connected to a STP (R.174.2.7). The default ERC 10B includes an assumption of sewage treatment applied to 80% of regional water emissions but also a requirement to include a local STP scenario. The exposure scenario in this document retains the local STP scenario with recommendations for refined emissions factors.

The guidance recognizes that the fate and behavior of particulate emissions is different than that of molecular emissions (R.17.4.2.4). For example, compounds in a particulate matrix may be more persistent but also less environmentally available to aquatic organisms. However, for Tier 1 screening in the absence of additional information, it is recommended in the guidance that substances in small particles be treated as if they were in the molecular form.

The availability of long term chemical specific degradation data for substances in TWP is limited. Cadle and Williams (1980) reported that the accumulation of TWP in a California roadside soil was equivalent to approximately five months of storage, or a total removal rate of 0.67% per day. Microbial degradation was believed to be a less important degradation mechanism than oxidation. Wind erosion and water runoff were also noted as potential removal mechanisms.

Chemical mobility in a vulcanized rubber matrix plays a role in an individual substance's release rate into the environment from a TWP. Most substances are cross-linked in the rubber matrix during vulcanization and characterized by low water solubility. Certain substances are not cross-linked and therefore theoretically able to leach from a TWP to varying degrees as a function of water solubility, diffusivity in the rubber matrix and weight content, including substances in TGD Class 03-Antidegradants, 05-Plasticisers, 06-1 Lubricants and Flow Improvers, 06-2 Tackifiers, unreacted Zn from the accelerator activator ZnO, and water soluble 02- Vulcanisation Agent transformation products such as benzothiazole and cyclohexylamine. Release of cross-linked substances in molecular form from a vulcanized TWP polymer is uncertain and not well studied. Given oxidation as the primary proposed mechanism for environmental degradation of a TWP, remaining cross-linked chemicals would be also subject to such oxidation, which make their direct release into the environment unlikely.

5.0 Local, Regional, and Continental Scales

In the EUSES model recommended for Tier 1 environmental exposure estimation under REACH, the local, regional and continental compartments correspond to default populations of 10 thousand, 20 million and 370 million inhabitants, respectively (EUSES 2.1 Background Report, Table III-193). The default population at the regional scale for REACH modeling represents a densely populated area in Western Europe and the local scenario represents a 'standard' town scenario (TGD R.16.2.1.5; App. R.16-1). The land surface area corresponding to a region is approximately 40,000 km^2 compared to a continental surface area of 7 million km^2. For wide dispersive uses, the default allocation of 10% of continental emissions to a region and 0.2% of regional water emissions to a STP are not realistic. The Netherlands, with population of approximately 16 million and land surface area of approximately 42,000 km^2 is comparable in scale to that of the default REACH region and can be used as an exemplar location to refine the regional ERC calculation. In addition, urban per capita TWP emissions can be derived for the Netherlands and used to refine the local STP scenario.

6.0 TWP Emission Factor – Regional and Continental

The TWP emission rate to the environment for the service life of the tyre can be calculated using either a sales approach or a distance travelled approach. The sales approach relies on estimates of the number of tyres sold by broad category (e.g. car, van, truck tyre) and an estimate of the fraction of the mass lost over the service life of the tyre. Assumptions about wear rate (i.e. mg TWP/km) are not required for the sales approach. The distance traveled approach relies on total distance traveled by broad category of tyre and an estimate of the wearing rate of the tyre. Past research has shown that similar annual regional TWP emission rates are estimated using either approach (Blok 2005). The current average tyre weight loss over the service life of a tyre has been estimated to range from 10% to 12% (Camatini et al., 2001, Blok 2005, OECD 2004). Historical estimates of tread rates from the 1970s are not reliable because modern radial tyres are characterized by a lower wear rate than the bias ply tyres used in the earlier time period (Veith 1992). The recommended loss fraction, representing a real-world end of life state for a modern tyre, is 11.5% for passenger and truck tyres (Blok 2005).

Continental Europe sales data from 1998 for passenger and truck tyres was provided by BLIC and presented in Blok (2005). Blok (2005) estimated van tyre sales using vehicle count and number of tyres per vehicle. Total tyre sales in 1998 equates to approximately 3.4 million tons tyre/year. The TGD Chapter R.16 indicates that the continental box includes the EU-15 and Norway, consistent with the data presented in Blok (2005). The estimated TWP emission rate in continental Europe is approximately 400,000 tons/year (Table 2). Using the TGD default assumption of 10% of emissions directed to a region, the approximate regional emission of TWP is 40,000 tons/year. Using the assumption of market share of 2.9% for the Netherlands (Blok 2005), the regional TWP emissions rate is 11,300 tons/year. Similarly, using an annual mileage approach, the TWP emission rate for the Netherlands is 12,200 tons/year, or 3% (Table

3). Therefore, the allocation of 10% of TWP to the theoretical region (or 40,000 tons/year) is not recommended, and recent EU Risk Assessment Reports (RARs) have also adopted more realistic regional emission rates.

Table 2: Annual TWP emission rate for continental Europe (adapted from Blok 2005).

Vehicle category	Car	Van	Truck
Sales in EU, millions/year 1998	256	35	17.5
Tyre weight (kg)	7.5	13.5	55
Average weight loss (%)	11.50%	11.50%	11.50%
Tread emission rate (ton/yr)	221000	54300	111000
		Total	390000

Table 3: Total TWP emission rate for the Netherlands region based on mileage for 2002 (adapted from Blok 2005).

Vehicle	Total Mileage (km x 10^{-9}/year)	Zinc Emission (mg/km)	Zinc Content (%)	Average Tread Emission[a] (mg/km)	Total Tread Emission (ton/year)
Car	93	0.83	0.95%	87.4	8125
Van	12.6	1.25	1.30%	96.2	1212
Freight	3.5	5.7	1.70%	335.3	1174
Bus	0.63	5.7	1.70%	335.3	211
Truck	2.9	8.5	1.70%	500.0	1450
					12200

[a]Vehicle basis.

Regional and continental estimates of TWP emission rates have been presented in recent EU RARs or can be derived from the information presented (Table 4). In both the final CBS and final Zn metal EU RARs, it was recognized that consideration must be given to the area and population of the region in developing TWP or chemical-specific emissions estimates. In the CBS RAR, the estimate for Germany was scaled to the default region by dividing by 4 to account for the difference in population between Germany and the model default region. In the Zn metal EU RAR, the Netherlands was selected as the representative region for exposure calculations because the total population and land surface area are similar to that in the TGD model. For informational purposes only, the Zn metal EU RAR also presented the results for the assumption 10% of emissions were directed to a single region. Based on the estimates in Blok (2005), the final EU RAR for CBS and the final EU RAR for Zn metal, the range of TWP emissions to a hypothetical region in the EU is 11,300 ton/year to 16,000 ton/year. The continental emission rate derived from these three references is between 330,000 to 390,000 ton/year. Regional and total continental TWP emissions rates of 12,200 ton/year and 400,000 ton/year, respectively from Blok (2005) is recommended.

Table 4: Recent estimate of continental and regional TWP emissions from EU RAR. Bold values indicate TWP emission rates selected for EU region and continent in EU RAR.

EU RAR	Location	People (million)	Total TWP emission rate (ton/year)	Fraction to air	Fraction to soil	Fraction to water	Fraction with municipal STP (water)
CBS	Continental EU	350	**360000**[a]	0%	33%	67%	50%
	Default Region	20	**16250**[b]	0%	33%	67%	50%
	Germany	80	65000[c]	N/A	N/A	N/A	N/A
Zn	Continental EU	350	**330000**[d]	4%	52%	44%	N/A
	Netherlands	16	**13800**[e]	4%	52%	44%	62%[f]
	Sweden	9	18900[g]	N/A	N/A	N/A	N/A
	Germany	80	68000[h]	N/A	N/A	8%[j]	N/A
Aniline	Germany	80	60000[i]	N/A	N/A	N/A	N/A

[a]From Blok (2002).
[b] Calculated in EU RAR by multiplying emission rate for Germany by population in default TGD region by population in Germany or 65000 x 20 million / 80 million.
[c]From Bauman and Ismeier (1998).
[d]An extrapolation factor of 24 from Netherlands region to continent was assumed in EU RAR based on ratio of driven kilometers.
[e]From Emissieregistratie 1999 (CCDM 2000 - Dutch Emission Inventory) Zn emission factors and mass weighted Zn content of 1.21% from Blok (2005).
[f]Calculated from emission inventory presented in Annex 3.2B in EU RAR.
[g]From Landner and Lindestrom (1998) and mass weighted Zn content of 1.21% from Blok (2005).
[h]From Arpaci (1998) and mass weighted Zn content of 1.21% from Blok (2005).
[i]From Bauman and Ismeier (1998).
[j]Estimate for total traffic-related Zn emissions.

7.0 TWP Emission Factor – Local

The default approach for ERC 10B specifies that 0.2% of regional water emissions, including articles used outdoors, be directed to a local STP. Using the Netherlands as an example with an estimate of 12,200 ton/year TWP released, this approach would result in an emission rate of 12,200 tons/year x 0.002 or 24 tons/year (66 kg/day) for a 'standard' community of 10,000 inhabitants. This equates to 2.4 kg TWP/year per capita.

A more realistic loading to the local STP can be derived by considering per capita TWP generation rates to maintain consistency with the 10,000 occupant capacity of the local STP for the 'standard' town. Using the mileage based estimate from Blok (2005), the overall TWP generation rate for the Netherlands is (12,200,000 kg/year) / (16,000,000 residents) or 0.76 kg TWP/year per capita. For the hypothetical 'standard community', the total emission rate of particles to the STP is 7.6 tons/year (21 kg/day).

The data presented in Blok (2005) shows that tread wear and annual vehicle miles traveled vary in rural and urban environments. The previous estimate does not take into account these differences. Storm water runoff is more likely to be directed to an STP in an urban environment than a rural environment. An upper bound estimate can be developed by considering urban area population and tread wear for the Netherlands. This estimate is considered to be an upper bound estimate because it is unlikely that 100% of storm water runoff in a community would be directed to the local STP. The United Nations (2005) estimates that 80.2% of the population in the Netherlands, or approximately 12.8 million people, are classified as urban. The data presented in Blok (2002, 2005) can be used to estimate urban, non-urban[1] and highway tread emissions in the Netherlands (Table 5). Using the urban TWP emission estimate of 5600 ton/year and the urban population count, the per capita TWP emission rate is (5,600,000 kg/year) / (12,800,000 residents) or 0.44 kg TWP/day per capita. This equates to 4.4 tons/year (12 kg/day) for the hypothetical 'standard community' and is the recommended emission rate for the sERC. Therefore, the recommended fraction of regional emissions to the local compartment is (4.4 tons/year) / (12,200 tons/year), or 0.036%.

Table 5: TWP emission rate by vehicle and location for the Netherlands region based on mileage for 2002 for urban roadways, non-urban roadways and highways (adapted from Blok 2005)[a].

	Mileage (km x 10^{-9}/year)			**Treadwear (mg/km)**			**Emission (ton/year)**		
Vehicle	**Highway**	**Non-urban**	**Urban**	**Highway**	**Non-urban**	**Urban**	**Highway**	**Non-urban**	**Urban**
Car	36.2	34.5	22.3	32	97	162	1171	3348	3607
Van	2.5	3.8	6.3	27	80	133	67	304	841
Freight	1.95	1.1	0.42	160	479	798	311	527	335
Bus	0.23	0.16	0.24	111	332	553	25	53	133
Truck	1.8	0.5	0.6	230	690	1151	414	345	690
							2000	4600	5600

[a]Average daily traffic intensity (ADTI) is 500 – 5000 for urban roads, 1000 to 1000 for non-urban roads and 20000 to 115000 for highways.

8.0 Allocation of TWP to Air, Soil and Water

The primary reservoirs for most substances contained in TWP are sediment (via discharge to water) and soil. The allocation of TWP to water and soil is based on an analysis of the literature by Blok (2005). The long term loading of Zn runoff in highways and main roads corrected for deposition was reviewed. Four studies were found that allowed calculation of the contribution of drift to the total Zn load, with a range of the contribution from drift equal to 21 to 53% of the contribution of runoff. It was concluded that on average over the course of a year, at most, 1/3 of the emission is removed by drift and 2/3 removed by run-off. This conclusion was adopted in the final EU RAR for CBS, with an assumption that 33% of TWP emissions are directed to soil and 67% are directed to water (see Table 4). The fraction of Zn from TWP released to soil assumed in the Dutch emission inventory of 52% appears to be an overestimate (see Table 4), although the literature review by Blok (2005) does indicate appreciable variability in Zn removal by runoff. For the sERC for the service life of a tyre, an allocation of 33% of TWP emissions to soil and 67% emissions to water is recommended.

Research indicates that the TWP content in airborne PM is low and most particles generated settle immediately after release. For example, Cadle and Williams (1978) reported that total

[1] Non-urban roads are termed 'regional area' roads in Blok (2005).

airborne particulate emissions account for less than 5% of total tyre wear. Similarly, Pierson and Brachaczek (1974) reported that airborne TWP accounts for 2-7% of total tyre wear and only 1 to 4% of total airborne particulate. The Dutch emissions inventory for Zn indicates that only 4% of TWP are directed to air (see Table 4). Therefore, in the refined sERC, the TWP emissions are assumed to be directed to water (and subsequently sediment) and soil given the low (but not quantified) percentage that is attributable to the airborne fraction.

9.0 References

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