Supplementary Information

Table S 1: Reported concentrations of TRWP related leachable compounds in various environmental matrices; DPU 1,3-diphenylurea, DCU 1,3-dicyclohexylurea, CPU 1-cyclohexyl-3-phenylurea, M-DCA 1,3-dicyclohexylmethylamine, BTR 1H-benzotriazole, 5-MBTR 5-methyl-1H-benzotriazole, 2-ABT 2-aminobenzothiazole, 2-MBT 2-mercaptobenzothiazole, 2-OHBT 2-hydroxybenzothiazole, 2-MTBT 2-methylthiobenzothiazole, BTSO3 benzothiazole-2-sulfonic acid, 24MoBT 2-(4-morpholinyl)benzothiazole, NCBA N-cyclohexyl-2-benzothiazolamine

Analyte	Sample	Mean	Min	Max	Unit	Reference
DPU	freshwater	38.7	0.64	839	ng/L	[1]
DPU	marine water	9.08	<0.58	62	ng/L	[2,3]
DPU	storm water	335	1.20	5,277	ng/L	[1,4]
DPU	marine sediment	0.33	0.20	1.70	µg/kg	[2,3]
DPU	WWTP influent	16.3	8.40	28.6	ng/L	[1]
DPU	WWTP effluent	8.79	5.40	13.6	ng/L	[1]
DCU	freshwater	102	1.40	552	ng/L	[5–10]
DCU	marine water	34.7	0.90	111	ng/L	[3,11,12]
DCU	storm water	525	1.20	3,232	ng/L	[4,12–14]
DCU	snow	14.2	0.50	169	ng/L	[13,15]
DCU	marine sediment	3.2	2.0	6.0	µg/kg	[3]
CPU	freshwater	18.8	<0.01	239	ng/L	[5,8–10]
CPU	storm water	125	1.9	395	ng/L	[13]
CPU	snow	9,082	2.26	22,632	ng/L	[13,15]
M-DCA	surface water	2.70	<0.3	26.0	ng/L	[1,5,8,10]
M-DCA	storm water	129	<0.15	11,120	ng/L	[1,4,13,14]
M-DCA	snow	5.28	2.01	23.0	ng/L	[13]
BTR	freshwater	186.6	0.32	2,078	ng/L	[5–8,10,16,17]
BTR	marine water	45.5	2.20	106	ng/L	[3,11]
BTR	storm water	92.7	0.10	7,400	ng/L	[4,12,16]
BTR	snow	22.8	12.7	39.6	ng/L	[15]
BTR	freshwater sediment	17.4	0.24	619	µg/kg	[17,18]
BTR	marine sediment	0.33	0.20	0.60	µg/kg	[3]
BTR	soil	44.0	<0.4	830	µg/kg	[19]
BTR	WWTP influent	3,900	2,520	5,100	ng/L	[20]
BTR	WWTP effluent	3,785	2,070	5,850	ng/L	[20]
5-MBTR	freshwater	256	<0.04	1,696	ng/L	[5–8]
5-MBTR	marine water	139	0.40	4,700	ng/L	[11,12]
5-MBTR	storm water	290	<0.04	2,200	ng/L	[12]
5-MBTR	snow	840	225	2,447	ng/L	[15]
5-MBTR	soil	170	1.10	4,100	µg/kg	[19]
5-MBTR	WWTP influent	630	397	1,160	ng/L	[20]
5-MBTR	WWTP effluent	612	349	820	ng/L	[20]
2-ABT	freshwater	7.76	0.21	167	ng/L	[1,5–8,16]
2-ABT	marine water	0.56	<0.09	2.43	ng/L	[2,12]
2-ABT	storm water	329	1.00	13,260	ng/L	[1,4,12,14,16]
2-ABT	marine sediment	0.20	<0.09	0.39	µg/kg	[2]
2-ABT	soil	17.3	<0.2	80.0	µg/kg	[1,19]
2-ABT	WWTP influent	106	1.23	276	ng/L	[1,20]
2-ABT	WWTP effluent	9.11	2.08	15.4	ng/L	[1,20]
2-ABT	tunnel wash water	285	71.0	394	ng/L	[21]
2-MBT	freshwater	50.6	1.37	1,110	ng/L	[1,17]
2-MBT	marine water		3	170	ng/L	[11]

Analyte	Sample	Mean	Min	Max	Unit	Reference
2-MBT	storm water	207	<0.3	3,760	ng/L	1,4,14
2-MBT	freshwater sediment	8.61	6.76	12.6	µg/kg	17
2-MBT	soil	10			µg/kg	22
2-MBT	WWTP influent	515	229	805	ng/L	1,20
2-MBT	WWTP effluent	<1.0			ng/L	1,20
2-MBT	tunnel wash water	<30			ng/L	21
2-OHBT	freshwater	222	<3.0	1,993	ng/L	1,5–8,10,17
2-OHBT	marine water	17.6	5.40	1,676	ng/L	2,3,12
2-OHBT	storm water	1,132	2.90	34,430	ng/L	1,4,12,14
2-OHBT	snow	1,130	275	2,421	ng/L	15
2-OHBT	freshwater sediment	4.78	1.85	16.8	µg/kg	17
2-OHBT	marine sediment	2.60	<1.38	6.25	µg/kg	2,3
2-OHBT	soil	46	2.10	270	µg/kg	19,22
2-OHBT	WWTP influent	345	22.3	568	ng/L	1,20
2-OHBT	WWTP effluent	137	9.78	217	ng/L	1,20
2-OHBT	tunnel wash water	8,233	2,986	13,914	ng/L	21
2-MTBT	freshwater	83.2	0.77	7,446	ng/L	1,5,8,16,17
2-MTBT	marine water	24.8	4.82	73.0	ng/L	2,3
2-MTBT	storm water	294	1.21	4,170	ng/L	1,4,14,16
2-MTBT	snow	214	49.0	658	ng/L	15
2-MTBT	freshwater sediment	3.78	0.55	11.4	µg/kg	17
2-MTBT	marine sediment	1.00	<0.24	2.02	µg/kg	2,3
2-MTBT	soil	27.0	<0.08	350	µg/kg	19,22
2-MTBT	WWTP influent	343	39.2	493	ng/L	1,20
2-MTBT	WWTP effluent	44.0	11.4	102	ng/L	1,20
2-MTBT	tunnel wash water	492	140	966	ng/L	21
BTSO3	marine water		47	820	ng/L	11
BTSO3	snow	32,282	216	75,171	ng/L	15
BTSO3	tunnel wash water	41,065	6,671	53,486	ng/L	21
24MoBT	freshwater	14.5	0.1	58.8	ng/L	5–8
24MoBT	storm water	39.0	5.90	88.0	ng/L	12
24MoBT	snow	13.9	6.32	23.1	ng/L	15
NCBA	freshwater	8.35	0.03	45.6	ng/L	5–8,16
NCBA	marine water	<2.7			ng/L	12
NCBA	storm water	0.44	0.10	100	ng/L	12,16

Table S 2: Reference list for Figure 1 "Environmental concentrations, L(E)C50 and NOEC of direct particulate tire wear exposure"

Compartment – concentration / test system	Species	Reference label	References
Freshwater - concentration	-	[a]	5,23–25
Freshwater - acute exposure	Green algae - *P. subcapitata*	[b]	26
	Western claw frog - *S. tropicalis*	[c]	27
	Fathead minnow - *P. promelas*	[d]	28,29
	Zebrafish - *D. rerio*	[e]	26,30
	Amphipod - *H. azteca*	[f]	31–33
	Waterlouse - *A. aquaticus*	[g]	31
	Water flea - *D. magna*	[h]	26,30,31,34,35
	Midge - *C. riparus*	[i]	36
Freshwater - chronic exposure	Green algae - *P. subcapitata*	[b]	26
	Zebrafish - *D. rerio*		
	Western claw frog - *S. tropicalis*	[c]	27
	Chinese mitten crab - *E. sinesis*	[j]	37
	Waterlouse - *A. aquaticus*	[g]	31
	Amphipod - *H. azteca*	[f]	31–33
	Water flea - *D. magna*	[k]	26,31
Freshwater sediment - concentration	-	[l]	23,24,38–43
Freshwater sediment - chronic exposure	Wood frog - *R. sylvatica*	[m]	44
	Amphipod - *G. pulex*	[n]	45
	Aquatic worm - *Tubifex*		
	Waterlouse - *A. aquaticus*		
	Midge - *C. riparus*	[j]	36
	Midge - *C. dilutus*	[o]	46
	Amphipod - *H. azteca*	[p]	31,46
	Blackworm - *L. variegatus*	[q]	31,45,47
Marine water - concentration	-	[r]	48,49
Marine water - acute exposure	Mummichog - *F. heteroclitus*	[s]	29
	Silverside - *M. beryllina*	[t]	50
	Opossum shrimp - *A. bahia*		
	Marine copepod - *T. japonicus*	[u]	51
	Eastern oyster - *C. virginica*	[v]	52
Marine water - chronic exposure	Mummichog - *F. heteroclitus*	[w]	53
Marine sediment - concentration	-	[x]	42,49
Marine sediment – chronic exposure	Clam - *S. plana*	[y]	54
	Ragworm - *H. diversicolor*		
Terrestrial - concentration	-	[z]	43,55–58
Terrestrial - acute exposure	White worm - *E. crypticus*	[aa]	59
	Tiger worm - *E. andrei*	[ab]	60
	Springtail - *F. candida*	[ac]	61
Terrestrial - chronic exposure	Red worm - *E. fetida*	[ad]	62
	Woodlouse - *P. scaber*	[ae]	63,64
	Springtail - *F. candida*	[af]	61,63
	Tiger worm - *E. andrei*	[ab]	60
	White worm - *E. crypticus*	[ag]	59,63,65
	Mung bean *V. radiata*	[ac]	61

Table S 3:Overview of tire particle leachate toxicity studies, x: effect observed, 0: no effect observed; -- no data available

Taxonomic group	Endpoint	Organism Tested	Tire Particle Leachate Study Preparations 0.1 - 1 g/L (n=9)	> 1 - 10 g/L (n=10)	> 10 - 100 g/L (n=12)	> 100 g/L (n=2)	Reference
Fish	Mortality	Zebrafish larvae (Danio rerio)	--	x	x	x	66–68
		Zebrafish embryo (Danio rerio)	--	--	0, x	--	30,67
		Fathead minnow	0	--	--	--	69
		Coho salmon	x	--	--	--	70
		Chum Salmon	0	--	--	--	70
	Reproduction	Fathead minnow, embryo	--	x	--	--	28
		Zebrafish larvae (Danio rerio)	--	x	0	--	67,68
	Growth / Development	Fathead minnow, embryo	--	x	--	--	28
		Zebrafish larvae (Danio rerio)	--	x	--	--	66–68
		Zebrafish embyro (Danio rerio)	--	--	x	--	30,67
	Other	Coho salmon	x	--	--	--	70
		Chum Salmon	0	--	--	--	70
Invertebrate	Mortality	Daphnia, magna	x*	x	x	x	30,34,35,66,67,69,71,72
		Daphnia, pullex	x	--	--	--	73
		Eriocheir sinensis	--	0	--	--	37
		Sinocalanus doerrii	x	--	--	--	73
		Pseudodiaptomus forbesi	0	--	--	--	73
		Mesocyclops leuckarti	0	--	--	--	73
		Thermocyclops taihokuensis	0	--	--	--	73
		Limnoithona tetraspina	0	--	--	--	73
		Moina micrura	x	--	--	--	73
		Diaphanosoma brachyurum	x	--	--	--	73
		Ceriodaphnia cornuta	0	--	--	--	73
		Brachionus calyciflorus	x	--	--	--	73
		Asplanchna sp.	x	--	--	--	73
		Keratella valga	0	--	--	--	73
		Paracentrotus lividus	x	--	--	--	74
		Arbacia lixula	x	--	--	--	74
		Diadema africanum	x	--	--	--	74
		Brachionus plicatilis	x	--	--	--	75
		Acartia tonsa	--	x	--	--	76
		Temora longicornis	--	x	--	--	76
		Centropages hamatus	--	x	--	--	76
		Oithona davisae	--	x	--	--	76
		Amonardia normanni	--	x	--	--	76
		Acartia longiremis	--	x	x	--	77
		Calanus	--	x	x	--	77
		Tigriopus japonicus	--	x	--		51
		Hyalella azteca	--	--	0	--	33
		A. albopictus	--	--	x	--	78
		A. triseriatus	--	--	x	--	78
	Reproduction	Brachionus plicatilis	x	--	--	--	79
		Mytilus galloprovincialis, adult	--	--	x	--	80–82
	Growth / Development	Daphnia, magna	--	x	--	--	66,69
		Brachionus plicatilis	x	--	--	--	79
		Paracentrotus lividus	x	--	--	--	74

Taxonomic group	Endpoint	Organism Tested	Tire Particle Leachate Study Preparations 0.1 - 1 g/L (n=9)	> 1 - 10 g/L (n=10)	> 10 - 100 g/L (n=12)	> 100 g/L (n=2)	Reference
		Arbacia lixula	x	--	--	--	74
		Mytilus galloprovincialis, embryo	--	--	x	--	82
		Diadema africanum	x	--	--	--	74
	Other	Brachionus plicatilis	x	--	--	--	79
		Paracentrotus lividus	x	--	--	--	74
		Mytilus galloprovincialis, adult	--		x	--	80–82
Algae	Growth	Raphidocelis subcapita	0	0, x	x	--	69,80,83
		Rhodomonas salina	x	--	--	--	84
		Thalassiosira weissflogii	x	--	--	--	84
		Heterocapsa steinii	x	--	--	--	84
		Scenedesmus obliquus	--	--	x	x	67
		Skeletonema costatum	--	--	x	--	80
		Chrorellat vulgaris	--	--	0	--	71
	Other	Ulva lactuca	x	--	--	--	85
Plant	Growth	Mung bean	--	x	--	--	66
		Lemna minor	--	x	x	--	71,86
Other (amphibian and bacteria)	Mortality	Silurana tropicalis	--	--	x	--	27
	Growth / Development	Silurana tropicalis	--	--	x	--	27
	Other	Activated sludge microbes	x	--	--	--	87

Table S 4: Components of PDF risk assessment framework for complex of microplastic particles (adapted from Koelmans et al. (2023)), and suitability or adaptation towards TRWP risk characterization.

[NO_PRINTED_FORM] [88] **Essential Component [#]**	**Proposed Risk Assessment Element of PDF Framework**	**Suitability or Adaptation for TRWP Risk Assessment & Communication**
Step 1 - Problem Formulation		
Particle effect mechanism [#13]	Quantifiable effects of food dilution and particle translocation	Suitable. Methods for environmental modeling and measurement of TRWP by mass are available [89,90]; single particle and laser diffraction methods are available for particle size determination [91,92]. Databases for particle effects are available in the PDF framework.
Additives [#4]	Chemical exposure PEC/PNEC approach informed by dose-response curves (#4)	Suitable. Elastomer additives, vulcanization products or environmental degradation products can be assessed by screening fugacity models such as EUSES used in REACH [93] informed by TRWP ecotoxicity literature or transformation studies (e.g.[94–96]) and screening for additive unknown and variable composition components and weathering products such as amine-based anti-oxidant functional degradation products [97,98].
Sorbed chemicals [#5]	Chemical exposure PEC/PNEC approach informed by dose-response curves	Suitable, but low priority. TRWP chemical sorption can be compared to sediment and suspended solids capacity, polymers have low abundance in sediment and thus are expected to be of minor importance to transport [99]. For example, recently reported TRWP median concentrations in Seine sediment (dry weight) were 0.03% and 0.3% in sediment and retained solids, respectively [23].
Open source tools [#15]	Accessible data or models such as the toxicity of Microplastics Explorer (ToMEx) web application	Suitable. Generalized microplastic toxicity data concerning food dilution and particle translocation available in ToMEx database. Several open-source fugacity modeling tools with local compartments such as the European Commission EUSES models can be used to assess additive safety. TRWP fate and transport models can be extended towards open source in the future either as part of global microplastics models or stand-alone models focused on TRWP.
Step 2 - Exposure and Hazard		
Bioavailability [#7]	Particle size vs. mouth opening or translocation barriers	Suitable. TRWP particle size distributions and aspect ratio have been characterized [91,100,101].
Effects [#8] and habitat [#11]	Particle effect thresholds for food dilution and particle translocation from standardized tests and synthesized in habitat-relevant SSDs; additive effects thresholds from chemical registration databases	Suitable with targeted TRWP-specific verification studies for sensitive species selected based on 1) classes of additive chemicals such as amine-based anti-oxidants [97] and 2) representation of differences in habitat. These studies should be performed under environmentally relevant conditions (e.g. [69,94,97]) of temperature, UV-weathered particles and water quality with environmentally relevant particles.
Physical properties [#1, #2]	Continuous probability density functions for size, shape and density (#1, #2)	Suitable, with modification to use probability mass function if necessary for watershed scale models. Probability mass functions for diameter, density and aspect ratio were applied in [90,102] watershed model. In principle, the PDF continuum of 1 to 5000 µm sized particles can be included, however, TRWP density of ~1.8 g/cm^3 restricts size range transportable to aquatic media.
Exposure scenario [#6]	Actual environmental concentrations (#6)	Suitable. Modeling and measurement methods available [89,90,100].
Step 3 - Risk Characterization and Communication		
Risk characterization [#12]	PEC/PNEC for food dilution, particle translocation and additives	Suitable with review of additive unknown and variable composition components and weathering products; formulated additives and known composition products already assessed under governmental chemical registration programs such as TSCA in the U.S. and REACH in the EU.
Risk Communication [#14, #16]	Coherence with existing risk assessment paradigms; policy-maker acceptance	Suitable. TRWP environmental risk can be communicated in the PDF framework using well-established terminology of the risk assessment paradigm consistent with regulations such as TSCA and REACH.

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