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MICROPROOF

Micropollutants in Road RunOff

Final Report: Sources, fate and treatment of microplastics and organic micropollutants from road transport

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1 Introduction

The goal of the Microproof project was to inform stakeholders on the sources, fate and treatment of microplastics and organic micropollutants from roads. For this purpose, a set of reports have been prepared to analyse this issue. This final report provides a practical summary of the research that has been conducted on this subject. For more details, it is advised to consult one of the underlying Microproof reports, available via www.microproof-cedr.nl/deliverables.php.

This report contains a practical summary of the set of Microproof reports. In chapter 2, the sources of microplastics and organic micropollutants are discussed. Chapter 3 contains a description of the pathways and concentrations in water and sediment. The concentrations are used to assess the risks of the pollutants in chapter 4, while potential treatment systems are discussed in chapter 5.

The following list contains a link between the chapters in this final report and the underlying Microproof reports:

- Chapter 2 Sources of microplastics and organic micropollutants
  - Report 1.1 - Review of literature on organic micropollutants, microplastics and associated substances in road run-off
  - Report 1.2 - Review of available measurements of organic micropollutants, microplastics and associated substances in road run-off
  - Report 1.3 - Combined results from the reviews of literature and measurements of organic micropollutants, microplastics and associated substances in road run-off
- Chapter 3 Microplastics and organic micropollutants in surface water
  - Report 2.1 - Pathways of organic micropollutants and microplastics in road borders
  - Report 2.2 - List of potential predicted environmental concentrations for microplastics and OMPs
  - Report 6.6 - Measurements of organic micropollutants, microplastics and associated substances from road transport
- Chapter 4 Risk assessment
  - Report 3.1 - Environmental Risk Assessment
- Chapter 5 Treatment systems
  - Report 4.1 - Processes and unit operations for road runoff management
  - Report 4.2 - Efficiency of treatment systems
  - Report 4.4 - Decision support scheme based on the risk assessment and the treatment efficiencies

All Microproof reports are available on www.microproof-cedr.nl/deliverables.php.

2 Sources of microplastics and organic micropollutants

2.1 Introduction

A large variety of pollutants is released from traffic and roads to the surrounding environment. This chapter provides an overview of the main sources and pollutants that are released from road transport. Microproof reports 1.1, 1.2 and 1.3 contains more details regarding the main sources and pollutants released from road transport.

Emissions from traffic and roads are caused by tyres-, asphalt- and concrete- abrasion, brakes, brake fluids, road markings, car coatings, corrosion inhibitors, automotive coolants, fuels, oils and lubricants. Also exhaust from traffic is a major source of emissions, but since these emissions are airborne, this source is not included in this study. Pollutants released by traffic and transport include solid particles, metals, microplastics and a large variety of organic micropollutants. This study only focusses on microplastics and organic micropollutants.

2.2 Microplastics

In this study, microplastics are defined as small plastic particles (< 5 mm), which are insoluble and slowly degradable. This also includes plastic particles from biogenic origin and rubber particles. Microplastics are released from a large variety of sources, including littering, households (laundry, beauty products, etc), paints and industry. Microplastics are also released from traffic and roads, including the wear of tyres (rubber particles), brakes, asphalt, road marking and vehicle parts. Tyre wear is deemed to be the largest source of microplastics emissions from traffic and roads, while microplastic emissions from road markings, brakes and asphalt are estimated to be a factor of 10 lower than microplastic emissions from tyres. Tyre particles are also a vector for other pollutants to the environment, like PAHs, several benzothiazoles and amines.

2.3 Organic micropollutants

The list of organic micropollutants released from cars and roads (as reported in Microproof report 1.3) is quite extensive, but still not complete. For some sources, no literature was available on the exact composition of the material and thereby on the exact composition of the emissions. However, this list presents a comprehensive overview of the main pollutants that are released from cars and roads. Table 1 provides an overview of selected relevant organic micropollutants.

This study revealed a variety of organic micropollutants that are released from road transport to the environment, but it was concluded that the number of actual measurements of individual components and quantities is limited. Nevertheless, for some of these pollutants, measurements have been reported in literature and/or preformed in this study (see chapter 3). It is recommended to perform more measurements in road run-off on organic micropollutants and microplastics (especially TWRP).

Table 1 Relevant organic micropollutants. This tables indicates whether the pollutant is a priority substance within the Water Framework Directive (WFD), and whether emission factors and/or concentrations in runoff have been reported in literature.

Source	Substance	Short name	CAS number	Priority substance in WFD	Emission factor in Microproof report 1.3	Concentration in runoff in Microproof report 1.3
Tyres	Benzothiazole	BT	95-16-9		X	X
	Mercaptobenzothiazole	MBT	149-30-4		X	X
	Benzothiazolone	BTON	934-34-9		X	
	Hydroxybenzothiazole	OHBT	934-34-9			X
	Benzothiazole-2-sulfonate	BTSA	941-57-1			X
	2-(methylthio)-benzothiazole	MTBT / MeSBT	615-22-5			X
	2-Morpholinobenzothiazole	24MoBT	4225-26-7			X
	Cyclohexylamine	CHA	108-91-8		X	
	Dicyclohexylamine	DCHA	101-83-7			
	Hydroxydiphenylamine	4-HDPA	122-37-2		X	
	Aminodiphenylamine	4-ADPA	101-54-2			
	Aniline		62-53-3		X	
	PAH			X	X	X
Brakes and brake fluid	Polyglycol ethers				X	
	Boric-acid-ester					
	Tributylphosphate		126-73-8			
	Triethanolamine		102-71-6			
	PAH			X	X	X
Car coatings	Hexa(methoxymethyl)melamine	HMMM	3089-11-0			X
	Nonylphenol ethoxylates	NP1EO, NP2EO	9016-45-9, 20427-84-3			X
	Octylphenolethoxylates	OP2EO, OP2EO	51437-89-9, 2315-61-9			X
	Bisphenol A	BPA	80-05-7			X
Coolants	Benzotriazole		95-14-7			
	Tolyltriazole	TT	29385-43-1			X
	Mercapto benzothiazole	MBT	149-30-4			X
Other	Diisodecyl phthalate	DIDP	26761-40-0			X
	Di(2-ethylhexyl)phthalate	DEHP	117-81-7	X		X
	Tris(1-chloropropan-2-yl) phosphate	TCCP	13674-84-5			X
	Nonylphenol monocarboxylate	NP1EC	3115-49-9			X
	Nonylphenol	NP	104-40-5	X		X
	4-tert-octylphenol	OP	140-66-9	X		X

3 Microplastics and organic micropollutants in surface water

3.1 Pathways from roads to surface water

Literature on microplastics and organic micropollutants concentrations in surface water is available, but the source of reported pollutants is not traceable. It is therefore difficult to indicate the share of traffic as a source for microplastics and organic micropollutants in surface water. Some models have been reported in literature to estimate the amount of microplastics from various sources in surface water.

To assess whether a pollutant poses an environmental risk in surface water bodies, the amount of pollutant that will end up in a surface water body should be quantified. The traffic volume and its composition, type of road pavement, the territory of the road, natural and climatic conditions (amount of rainfall, wind direction and speed), and geophysical conditions (relief, vegetation, type of soil, engineering - geological and hydrological conditions which in turn are characterized by the conditions of runoff, water evaporation, snow cover thickness and intensity of spring snow melting, depth of groundwater occurrence and features of their regime, regimes of surrounding rivers and streams) have a direct or indirect impact on the amount and spread of micropollutants in the roadside environment.

Depending on several road characteristics, either runoff or drift is the most important pathway from roads to the environment. Runoff will infiltrate in the verge and most pollutants will remain in the soil, except for pollutants with high solubility which can be transported to the groundwater. Runoff can also be treated in storm water treatment systems and the effluent is then discharged in surface water. This can be a direct discharge or via a sewer, connected to a wastewater treatment plant. Pollutants will also be transported from the road via drift (the airborne route of splash and spray from the road). Research indicates that the pollutants will be deposited within a few 100 meters (or closer) from the road and can thus directly impact surface water bodies.

3.2 Predicted environmental concentrations

To assess the environmental risk of a pollutant, it needs to be known what the concentration of that pollutant in a surface water body is. Therefore, for the risk assessment, predicted environmental concentrations (PECs) need to be derived. Within this project the PECs were derived for a selection of pollutants, based on literature and on new measurements. In total 11 pollutants were selected for the environmental risk assessment (microplastics and 10 organic micropollutants).

Table 2 provides the PECs of the selected pollutants, to be used in the risk assessment. The PECs from literature are shown in red, while the PECs from actual new measurements are shown in black.

Table 2 Predicted environmental concentrations in runoff and surface water from measurements in Sweden (SE E18), Germany (DE A61) and the Netherlands (NL A2 and NL Rhine) (in black) and from literature (in red).

Medium	Runoff				Surface water				
	Water (µg/l)		Suspended solids (µg/g)		Water (µg/l)		Suspended solids (µg/g)		
Location	**DE A61**	**SE E18**	**DE A61**	**SE E18**	**NL A2**	**Esti-mate**	**NL A2**	**NL Rhine**	**Esti-mate**
Rubber (tyre wear)	59000	980	150000	13000	6.0	120	300	300	1200
Benzo(a)pyrene	0.0012	0.00081	0.94	0.21	0.00011	0.0083	0.073	0.24	0.083
Fluoranthene	0.0030	0.0031	2.4	0.30	0.0011	0.036	0.17	0.45	0.36
Nonylphenol	<0.01	<0.01	<0.001	<0.001	<0.01	0.0036	0.021	0.0011	0.031
4-tert-octylphenol	0.20	0.016	1.5	0.53	<0.01	0.00060	<0.001	0.0042	0.0060
Di(2-ethylhexyl)phthalate	0.66	0.72	65	2.4	0.98	0.023	10	14	0.98
Bisphenol A	0.028	0.10	0.24	0.056	<0.01	0.0055	<0.001	0.0053	0.055
Mercapto benzothiazole	<0.01	<0.01	1.0	0.19	<0.01	0.0011	0.0023	<0.0001	0.011
Tolyltriazole	<0.01	0.40	1.1	0.039	<0.01	0.023	0.0058	0.0064	0.23
Diisodecyl phthalate	2.6	0.60	140	4.6	<0.001	0.086	2.0	0.65	0.86
Hexa(methoxymethyl)melamine	3.9	2.2	0.032	0.0017	0.071	0.0088	<0.001	<0.001	0.088

Note: The concentrations from literature (indicated in red) are uncertain as this is based on the highest literature concentrations in runoff combined with an assumed dilution of 1/100.

3.2.1 PECs based on literature

PECs are based on the highest reported concentrations from literature. For microplastics, the highest modelled tyre wear concentration in surface water is used, while for the organic micropollutants, the highest reported concentration in runoff is used multiplied with a dilution factor of 1/100. Microproof report 2.2 provides more details regarding the literature and calculation of these PECs.

3.2.2 PECs based on actual new measurements

In this study, actual new measurements were performed for the following sites:

- Runoff and soil from the highway A61 in Germany
- Runoff, soil, sediment and road surface dust from the highway E18 in Sweden
- Surface water and sediment from a surface water body next to the highway A2 in the Netherlands
- Suspended solids in the Rhine in the Netherlands

In the samples from these sites, concentrations were measured of microplastics (tyre wear particles only), polycyclic aromatic hydrocarbons (PAH), octylphenol- and nonylphenol ethoxylates (OPEO and NPEO), phthalates, phenols, benzothiazoles, benzotriazoles, amines and metals.

Tyre wear particles were measured in all the samples. The marker 4-vinylcyclohexeen was used to measure and calculate the tyre wear concentration. As a check, the tyre wear concentration was also calculated with ZnO, sulphur and black carbon as markers. Concentrations calculated from ZnO, sulphur and black carbon are less accurate, because these substances could also be released from other sources. However, these checks showed that the measured concentrations are within the same order of magnitude.

Measured tyre wear concentrations in runoff are 1.0 and 59 mg/l for the Swedish and German site respectively, while measured tyre wear concentrations in surface water are 0.0108 and 0.006 mg/l for the river Rhine and the water body next to the A2 respectively.

Most of the selected transport related organic micropollutants were detected in runoff and in surface water. The average daily traffic in Germany was higher than the average daily traffic in Sweden, and this is also reflected in the concentrations of most pollutants. The concentrations in the German samples are in most cases higher than the concentrations in the Swedish samples. This could partly be explained by the sampling method.

The results from the measurements of organic micropollutants (excluding PAH) are in the same order of magnitude as the concentrations reported in literature. Differences can most likely be explained by the differences between the different sites. For PAH, the upper range of the runoff concentrations reported in literature are for most pollutants (much) higher than the measured concentrations in runoff in Germany and Sweden. This can partly be explained by the fact that the reported concentrations in literature are for a large part from before 2010, when Directive 2005/69/EC (which a.o. banned the use of PAH in tyres) came into force. Concentrations in surface water are a factor 10-1000 lower than concentrations in runoff.

A selection of the results is presented in Table 2. Microproof report 6.6 contains a more extensive description of the sites, the analyses and the results of the measurements.

4 Risk assessment

4.1 Introduction

The environmental risk assessment is performed for the selected 11 pollutants (microplastics and 10 organic micropollutants). The environmental risk assessment involves two types of risk assessment (first tier and second tier):

- Risk categorisation (first tier); Within the first tier the Predicted Environmental Concentration (PEC) of selected substances is compared with the sensitivity of the environment (Predicted No-Effect Concentration (PNEC)). The PECs are taken from Table 2 and PNEC values are based on literature or are derived using available toxicity data.
- Quantification of risk (second tier). Within the second tier, a Species Sensitivity Distribution (SSD) is derived for each of the selected substances, based on No Observed Effect Concentration (NOEC) values from literature and using the software ETX 2.1. The SSD is used to represent the sensitivity of the environment. The PEC compared with the SSD indicates the probability that a specific fraction of species is exposed above their NOEC value. This is reported as the Potentially Affected Fraction of species (PAF), in percentage, at the exposure concentration.

Microproof report 3.1 contains more details on the environmental risk assessment.

4.2 Risk assessment of organic micropollutants

Table 3 provides an overview of the PEC/PNEC ratios from the environmental risk assessment of water and sediment in runoff and surface water.

The performed risk assessment shows that for most of the selected OMPs, the risks from road traffic for the European waters are within acceptable limits. Estimated concentrations in surface water based on values found in literature indicate risks (i.e. unacceptable effects are not unlikely) for benzo(a)pyrene and fluoranthene. Measured concentrations of the selected OMPs in surface water (samples taken in a small waterway near the busy highway A2 in the Netherlands) are, however, all below the PNEC, indicating unacceptable effects are unlikely. For OMPs in sediment, estimated concentrations based on literature values indicate risks for 4-tert-octylphenol and tolyltriazole. However, measured concentrations in sediment show the PEC/PNEC ratio to be > 1 only for tolyltriazole.

The higher tier risk assessment, using the estimated (from literature) as well as measured concentrations in surface water, indicates that for benzo(a)pyrene, fluoranthene and di(2-ethylhexyl)phthalate the risk may be above acceptable limits. The risk of nonylphenol, 4-tert-octylphenol, bisphenol A and mercaptobenzothiazole in surface water is within acceptable limits. The PAFs for tolyltriazole, diisodecyl phthalate and hexa(methoxymethyl)melamine and the PAFs for exposure via sediment could not be estimated due to data limitation.

For OMPs in road runoff, the first tier risk assessment show PEC/PNEC ratio's > 1 for benzo(a)pyrene, 4-tert-octylphenol and diisodecyl phthalate in the water phase and for fluoranthene, 4-tert-octylphenol, bisphenol A, mercaptobenzothiazole, tolyltriazole and diisodecyl phthalate in the solid phase. The higher tier risk assessment shows that for 4-tert-octylphenol and di(2-ethylhexyl)phthalate the risk may be above acceptable limits.

Table 3 Ratio between Predicted Environmental Concentration and Predicted No-Effect Concentration (PEC/PNEC) from Microproof report 3.1.

Medium	**Runoff**				**Surface water**				
	Water		**Suspended solids**		**Water**		**Suspended solids**		
Location	**DE A61**	**SE E18**	**DE A61**	**SE E18**	**NL A2**	**Esti-mate**	**NL A2**	**NL Rhine**	**Esti-mate**
Rubber (tyre wear)	*177273*	*2955*	*1500000*	*130000*	*18*	*364*	*3000*	*3000*	*12000*
Benzo(a)pyrene	6,9	4,8	0,5	0,1	0,6	48,8	0,0	0,1	0,0
Fluoranthene	0,5	0,5	1,2	0,2	0,2	57,9	0,1	0,2	0,2
Nonylphenol	0,0	<	0,0	<	<	0,0	0,0	0,0	0,0
4-tert-octylphenol	2,0	0,2	907,5	329,1	<	0,0	<	2,6	3,7
Di(2-ethylhexyl)phthalate	0,5	0,6	0,7	0,0	0,8	0,0	0,1	0,1	0,0
Bisphenol A	0,0	0,1	3,9	0,9	<	0,0	<	0,1	0,9
Mercapto benzothiazole	0,0	<	6,9	1,3	<	0,0	0,0	<	0,1
Tolyltriazole	0,0	0,0	366,2	13,1	<	0,0	1,9	2,1	76,7
Diisodecyl phthalate	4,3	1,0	42,3	1,4	<	0,1	0,6	0,2	0,3
Hexa(methoxymethyl)melamine	0,1	0,0	0,2	0,0	0,0	0,0	<	<	0,7

Notes:

- The cells that are highlighted with yellow in this table indicate the concentrations for which the PEC is higher than the PNEC, and these pollutants may cause a risk for the aquatic environment.
- The PEC/PNEC ratios of tyre wear (indicated in italics) are uncertain due to the fact there is no specific PNEC value available for tyre wear particles (see Microproof report 3.1)
- The PEC/PNEC ratios based on literature (indicated in red) are also uncertain as the PEC ratios are based on the highest literature concentrations in runoff combined with a dilution of 1/100.

4.3 Risk assessment of microplastics

Table 3 provides an overview of the PEC/PNEC ratios of microplastics from the environmental risk assessment of water and sediment in runoff and surface water. The SSD for microplastic is considered as an “all-inclusive” SSD and not specific for tyre wear particles. For microplastics, based on the rough estimates for exposure and the “all-inclusive” SSD, unacceptable effects cannot be ruled out for exposure via water and sediment. However, it should be noted that the PEC, PNEC and PAF for microplastics should be interpreted with care due to the high uncertainty of measured PEC values and heterogeneity of the tested microplastic used for PNEC derivation considering polymer type, size and shape. Additional research is required for a risk assessment specifically for tyre wear particles.

4.4 Whole Effluent Toxicity tests (WET-tests)

To support the above reported risk assessment, bioassays (the so called WET-tests) were performed. The results of these tests represent the toxicity of all substances present in the samples. WET-tests of the surface water (a small waterway near highway A2, the Netherlands) show no significant toxic effects for bacteria, algae and crustacean. The WET-tests of road runoff from Germany and Sweden show no significant toxic effects for bacteria and crustacean. However, the algae growth inhibition test of the runoff samples showed significant dose-related growth inhibition.

5 Treatment systems

This chapter gives an overview of the current knowledge on treatment systems for microplastics and organic micropollutants. More details are available in Microproof reports 4.1, 4.2 and 4.4.

5.1 Introduction

The processes that are involved in retaining OMP and MP in road runoff treatment systems, or for that matter in urban stormwater ponds, are still only understood at a rather generic level. Detailed knowledge of what exactly goes on in terms of physical, chemical, and biological processes in these systems is generally lacking. As a consequence, the prediction of which substances and materials can be detained to what extent by which treatment system configuration will be similar generic. In other words, statements like “fluoranthene is retained rather efficiently in a soil filtration system because it has a high K_{OW}-value” can be put forward and also statements like “fluoranthene will likely be contained more efficiently in a soil filtration system than acenaphthylene, because the latter has a lower log K_{OW} value (5.16 and 3.93, respectively)”. However, deduction of the actual retention rate in a specific system from theoretical knowledge only is not possible yet. To gain the information needed for such exercises, there is a need for more experimental studies and investigations on the behaviour substances and systems in question. From such new data one might then make some guestimates on retainment efficiency for similar substances, extrapolating our knowledge from the obtained database.

The only organic micropollutants for which there are some data on treatment efficiencies are PAH. Other data are scarce and either not measured at all or to a degree where no general conclusion can be drawn. The same is the case for microplastics, where no data what so ever exists on the efficiency of stormwater treatment systems. Several studies have addressed this issue by establishing process-based models.

While these attempts to model the treatment performance all have their uses, they fall short when it comes to predicting the behaviour of a novel pollutant. For example microplastics: While it is quite obvious that systems which are good at retaining organic particles are likely also good at retaining microplastics (because the density and properties of the two particle types have similarities), such conclusion is only valid in qualitative terms. Similarly, it is quite obvious that an unknown substance with a high log K_{OW} value will be retained in systems that retain other substances with high log K_{OW} values, as the sorption processes leading to the removal are similar. However, this is again a statement that can only be made in qualitative terms.

5.2 Qualitative efficiency of treatment systems

A simple qualitative overview of the fate of organic micropollutants that have not yet been measured is given in Table 4. For example, if a substance is easily degradable and sorbs easily to solids, it has a high probability of being retained/removed in all types of treatment systems. If it, on the other hand, is slowly degradable and sorbs poorly to solids, it most likely will not be much affected by any system, and the least affected by systems with a short hydraulic residence time. Comparing the approaches laid out below, one can in very general terms furthermore say that systems based on slow soil filtration will tend to achieve the higher removal rates. However, this is only true as a general trend, and the actual efficiencies will depend on the actual layout and design of the systems.

Table 4 A qualitative assessment of the fate of substances in different types of treatment systems

Type of treatment system	Degradability	Particulate or sorbs well to solids	Sorbs poorly to solids
Stormwater management facility applying a wet retention volume	Easily degradable		
	Slowly degradable or inert		
Stormwater management facility applying (slow) soil filtration	Easily degradable		
	Slowly degradable or inert		
Stormwater management facility applying (rapid) soil filtration	Easily degradable		
	Slowly degradable or inert		
Stormwater management facility applying technical (rapid) filtration or ballasted sedimentation	Easily degradable		
	Slowly degradable or inert		

An example of an unknown substance could be car tyre debris and tyre wear and road particles, on which there exists no measurement data what so ever. These are particles which probably behave similar to other organic particles of similar size, and hence likely are removed by processes and to degrees similar to these. Further indication of this is the observation that microplastics in general seem to be retained similar to particulates, and it seems likely that tyre particles would behave similar.

Summing up, our knowledge on the efficiency of specific treatment solutions towards the wide range of organic micropollutants and microplastics that can be found in road and highway runoff is very limited. The state of knowledge does not allow a detailed assessment of treatment efficiencies and discharge concentrations, but only a qualitative assessment based on treatment system and pollutant characteristics.

5.3 Decision support scheme

The combined result of the risk assessment and the (qualitative) analysis of the performance of different treatment systems is shown in Annex 1. The table, which is to be used as a decision support scheme for selecting appropriated treatment systems, is an addition to national and or regional regulations on road-design and stormwater treatment obligations. These regulations and obligations determine whether or not a specific stormwater treatment system should be installed. The decision support scheme can be used additionally to select the most appropriate treatment system. The scheme should be used with due care as it is based on the results of this exploratory study. Local experience from existing systems (amongst others chemical analysis of runoff, performance indicators and level of maintenance) should also be included in the final design and investment decisions.

Annex 1 shows that tyre wear particles, benzo(a)pyrene, fluoranthene, 4-tert-octylphenol and tolyltriazole may cause a risk for surface water quality. Tyre wear particles, benzo(a)pyrene, fluoranthene and 4-tert-octylphenol are probably removed efficiently in different kinds of treatment systems (based on the Log K_{OW} and the degradability of the pollutants).

Tolyltriazole is removed less well. For such substances one typically would typically select a chemical oxidation system, which is not realistic when it comes to stormwater treatment. Alternatively, one could probably reach some degradation with very slow filtration through organic rich soils (meaning that you need a low surface loading on your soil filter). Which could be achieved when infiltrating continuously along the road side (ditch, road shoulder). The achievable effectivity is difficult to predict.

6 Conclusion

Road traffic is a source of a diversity of environmental relevant compounds, ranging from microplastics (mainly tyre wear and road particles) to a variety of organic micropollutants. These pollutants can reach the water environment mainly via runoff and airborne drift. A first risk assessment based on literature data and new measurements indicate that environmental risks cannot be excluded.

The results of this exploratory study show that currently used mitigation options (like verge infiltration or storm water ponds) are expected to have sufficient efficiency to reduce the environmental risk to an acceptable level.

However, these conclusions are based on a limited number of samples and some (local) parameters determine the expected actual concentrations in runoff and thus the associated risks. Some results indicate that the adverse effects to water organisms of TRWP and some micropollutants cannot be ruled out. This indicates that, in those situations where there is no regulation in place (which demands additional abatement), such basic mitigation measures would be sufficient. Investments in additional or advanced abatement measures should be based on specific studies tuned to the specific local situation.

Microproof has delivered a simple to use methodology to select appropriate treatment system based on the expected qualitative effectiveness of the measures. Application of this tool will help to minimize the effect of runoff on the water quality. It is recommended to use this methodology in the above-mentioned site specific studies, in combination with the report on treatment systems.

It is recommended to follow the research in this field and where possible to join forces with ongoing research.

7 Acknowledgement

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Annex A: Decision support scheme

Pollutant		Pollutant characteristics			Risk Assessment													Types of treatment systems			
					Runoff						Surface water							Wet retention volume	Slow soil filtration	Rapid soil filtration	Technical rapid filtration or ballasted sedimen-tation
					Water				Suspended solids		Water				Suspended solids						
					DE A61		SE E18		DE A61	SE E18	NL A2		Estimate		NL A2	NL Rhine	Esti-mate				
Pollutant	**CAS number**	**Degradable**	**log Kow**	**XLogP 3**	**PEC/ PNEC**	**PAF**	**PEC/ PNEC**	**PAF**	**PEC/ PNEC**	**PEC/ PNEC**	**PEC/ PNEC**	**PAF**	**PEC/ PNEC**	**PAF**	**PEC/ PNEC**	**PEC/ PNEC**	**PEC/ PNEC**				
Rubber (tyre wear)		Slow			*177273*	*86%*	*2955*	*61%*	*1500000*	*130000*	*18*	*22%*	*364*	*44%*	*3000*	*3000*	*12000*	+	+	+	+
Benzo(a)pyrene	50-32-8	Slow	6,13	6	6,9	0,5%	4,8	0,4%	0,5	0,1	0,6	0,1%	48,8	2,1%	0,0	0,1	0,0	+	+	+	+
Fluoranthene	206-44-0	Slow	5,2	5,2	0,5	0,1%	0,5	0,2%	1,2	0,2	0,2	0,1%	57,9	1,3%	0,1	0,2	0,2	+	+	+	+
Nonylphenol	104-40-5	Moderate	4.48 - 5.4	5,9	0,0	0,2%	<	0,2%	0,0	<	<	0,2%	0,0	0,0%	0,0	0,0	0,0	+	+	+	+
4-tert-octylphenol	140-66-9	Easily	4,12	5	2,0	0,2%	0,2	0,0%	907,5	329,1	<	<	0,0	0,0%	<	2,6	3,7	+	+	+	+
Di(2-ethylhexyl)phthalate	117-81-7	Moderate	4.8 - 9.6	7,4	0,5	3,6%	0,6	3,8%	0,7	0,0	0,8	4,9%	0,0	0,1%	0,1	0,1	0,0	+	+	+	+
Bisphenol A	80-05-7	Easy	3,4	3,3	0,0	0,1%	0,1	0,3%	3,9	0,9	<	0,0%	0,0	0,0%	<	0,1	0,9	+	+	+	+
Mercapto benzothiazole	149-30-4	Slow	2,86	2,4	0,0	<	<	<	6,9	1,3	<	<	0,0	0,0%	0,0	<	0,1	+/-	+/-	-	-
Tolyltriazole	29385-43-1	Slow	1,081	1,4	0,0	NA	0,0	NA	366,2	13,1	<	NA	0,0	NA	1,9	2,1	76,7	+/-	+/-	-	-
Diisodecyl phthalate	26761-40-0	Moderate	8,8	10,6	4,3	NA	1,0	NA	42,3	1,4	<	NA	0,1	NA	0,6	0,2	0,3	+	+	+	+
Hexa(methoxymethyl)melamine	3089-11-0	Moderate	1,61	1	0,1	NA	0,0	NA	0,2	0,0	0,0	NA	0,0	NA	<	<	0,7	-	-	-	-

XLogP3 Source: https://pubchem.ncbi.nlm.nih.gov/
log Kow Source: see Microproof report 3.1

This scheme combines the results of the risk assessment with the results of the treatment systems. A red colour in the risk assessment means that the pollutant may cause a risk for the aquatic environment. A red colour in the treatment systems means that the treatment system may not be appropriate for treating a certain pollutant. Please note that the results of the risk assessment for tyre wear is uncertain (see Microproof report 3.1).

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