Microplastics and Contaminants of Concern in the Strategic Road Network

Specialist Professional & Technical Services 2 (SPaTS 2)
(April 2023)

Reference Number: T0051

Client Name: National Highways

This document has been issued and amended as follows:

Version	Date	Description	Created by	Verified by	Approved by
V1.0	27/01/2023	Draft for client review	H Gibbs, J Brammer	M Blackmore	B Cox
V2.0	22/02/2023	Draft final	H Gibbs, J Brammer	M Blackmore	B Cox
V3.0	12/04//2023	Final	H Gibbs	J Brammer	M Blackmore

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Non-Technical Executive Summary

The environmental abundance of microplastics is a growing area of concern. There is an increasing body of evidence to suggest that the road network is a potentially important source area to surrounding aquatic environments. National Highways have a statutory responsibility to not pollute the water environment and acknowledge this emerging area of interest. They have commissioned this second Phase of research to understand the scale of issues and key factors related to microplastics (and contaminants of concern) in the context of the Strategic Road Network (SRN).

A literature review supplement has been produced building upon that carried out in Phase 1 and should be read in conjunction with the original literature review. The standardization of analytical techniques remains a challenge as different methods, and units, are necessary to measure tyre wear particles (TWPs) when compared to other microplastics. The literature identifies a need to investigate the factors that influence microplastic pollution from roads.

Led by Professor Richard Thompson from the University of Plymouth a monitoring programme has been devised to quantify the contribution of TWPs and other types of microplastics from the SRN to aquatic environments. This programme is focussed on understanding the scale of microplastics in road runoff from the SRN as well as the efficacy of existing highway drainage systems. In addition the research set out to understand if contaminants of concern not monitored during previous National Highways research into road runoff, are present at concentrations of concern. .

The findings of this programme have considerably added to our understanding of the extent and sources of TWPs and other microplastics associated with the SRN. This study concludes highway runoff to be a significant source of anthropogenic debris, including microplastics, to aquatic ecosystems, with TWPs found to contribute a greater mass than other forms of microplastics. Although showing some variability, the removal of TWPs was typically effective within drainage ponds on the network. These findings are agreeable with previous research and have the potential to contribute towards improving the design, location and maintenance of highway drainage systems targeted towards reducing pollutant loading to surrounding environments.

While runoff samples were collected for microplastic analysis, additional water samples were collected from a small number of sites for further chemical analysis. Average concentrations of 13 contaminants exceeded the standards used as an environmental benchmark. The absence of environmental standards for many of these pollutants meant that it was not possible to make an assessment of the risk posed to the aquatic environment. In all instances in this study, the Highways England Water Risk Assessment Tool (HEWRAT) generates copper and zinc concentrations that are comparable to the sample data; however, a wider study would be beneficial to analyse the robustness of this claim.

1. Nomenclature

1.1. Abbreviations

4t-OP	4-tert-octylphenol
6:2 FTS	6:2 Fluorotelomer sulfonic acid
6PPD	N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine
24MoBT	2-(4- morpholinyl)benzothiazole
AADT	Annual average daily traffic
ABS	Acrylonitrile butadiene styrene
ANOVA	Analysis of variance
BT	Benzothiazole
BTSA	Benzothiazole-2-sulfonic acid
CVAF	Cold Vapor Atomic Fluorescence
CWG	Clean Water Group
DMRB	Design Manual for Roads and Bridges
DPG	1,3-diphenylguanidine
d.w.	Dry weight
EA	Environment Agency
EQS	Environmental Quality Standard
FTIR	Fourier-transform infrared spectroscopy
FTS	Fluorotelomer sulfonic acid
GC	Gas chromatography
HADDMS	Highways Agency Drainage Data Management System
HEWRAT	Highways England Water Risk Assessment Tool
HMMM	Hexa(methoxymethyl)melamine
LOD	Limits of detection
LOQ	Limits of quantification
MP	Microplastic
MS	Mass spectrometry
NCBA	N-cyclohexyl-2-benzothiazolamine
PA	Polyamide (nylon)
PAH	Polycyclic aromatic hydrocarbon
PBT	Polybutylene terephthalate
PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene terephthalate
PES	Polyester
PFAAS	Perfluoroalkyl Acids

PFOS	Perfluorooctanesulfonic acid
PNEC	Predicted No Effect Concentration
PP	Polypropylene
PS	Polystyrene
PSG	Project Steering Group
PU	Polyurethane
PVA	Polyvinyl alcohol
PVC	Polyvinyl chloride
Py-GC-MS	Pyrolysis–gas chromatography–mass spectrometry
SAAR	Standard Annual Average Rainfall
SAN	Styrene acrylonitrile co-polymer
SMC	Sheet moulding compound
SRN	Strategic road network
SuDS	Sustainable Drainage Systems
SVOC	Semi-Volatile Organic Compound
TIC	Toxic Industrial Chemical
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
TRWP	Tyre, road and wear particles
TWP	Tyre Wear Particle
UKAS	United Kingdom Accreditation Service
VOC	Volatile Organic Compounds
WFD	Water Framework Directive
Zn	Zinc

1.2. Glossary of terms[1]

Direct runoff	Surface water runoff collected from drainage outfalls on curved or straight sections of the SRN, or as wetland or retention pond influent.
MP	Microplastic (small pieces of plastic debris (<5mm) that are insoluble in water, solid in state, persistent in the environment, and synthetic in composition
Other microplastics	Small particles made of synthetic polymers, excluding any material originating from the wear and tear of tyre tread.
Retention Pond	A pond that generally retains some water at all times. Can have permeable base or banks. Primarily designed to attenuate flows by accepting large inflows, but discharging slowly. Can also treat water by allowing suspended solids to settle out.
Wetland	A pond with a high proportion of shallow zones that promote the growth of bottom-rooted plants, and which can be used for treatment of pollution.

[1] Definitions are specific to this report, they are not necessarily applicable outside the context of this piece of work.

2. Introduction

National Highways has a responsibility to ensure their understanding of the environmental effects associated with the strategic road network (SRN) is up to date, and that the assessment and design guidance standards which are published and maintained in the Design Manual for Roads and Bridges (DMRB) are robust.

Tyre, road and wear particles (TRWP) (including road paint markings) as well as roadside plastics litter were identified in Microplastics 1 (Phase 1 of this project) as the likely main source of microplastics from the SRN, both of which are from secondary sources (i.e. degradation sources) (Highways England, 2020). This was confirmed in the Defra Evidence review on sources of microplastics found in freshwater environments (Defra, 2019). The pathway of runoff (via storm water discharges) was identified as probably the most important pathway for tyre particles to the environment (compared to deposition from the air and wastewater treatment works) (Parker-Judd *et al.,* 2020). To identify whether any changes are required to National Highways current policy, it is necessary to address existing gaps in our understanding which are widely acknowledged (Committee on Toxicity, 2020). An additional complexity with microplastics is that chemicals are known to sorb to their surface (Robin *et al.,* 2020) and leach out (e.g. 6PPD-quinone; Tian *et al.,* 2021), meaning they not only form a pathway for movement of chemicals in the environment but also have an associated chemical toxicity risk.

In 2019 cycle 3, the Environment Agency reported that 100 % of water bodies were failing to meet a ‘Good’ chemical status under the Water Framework Directive (Environment Agency, 2021)[2]. This has been attributed to improvements to its monitoring which involved searching for the presence of substances in fish and shellfish as well as in water. However, this spotlight on chemicals will drive further investigation into sources and control measures, including the recent House of Commons Environmental Audit Committee inquiry into water quality in rivers. Recent reviews of stormwater quality consider that historical data may now be out of date and does not consider releases of new substances of potential concern, which suggests this continues to be an area in need of further research (Müller *et al.,* 2020).

It is therefore important for National Highways to address any recognised knowledge gaps and identify (either as a result of microplastics or chemicals of concern) if any changes are required to the dataset that underpins tools that inform design and assessment, such as the Highways England Water Risk Assessment Tool (HEWRAT). Recommendations require consideration of whether changes are required to current drainage standards (the DMRB LA 113; Road Drainage and the Water Environment and Design of Highway Drainage Systems DMRB CG 501).

These knowledge gaps relate to: the scale of microplastics present in highway runoff, how this is influenced by different factors, the extent of any new contaminants of concern, and any updates required to HEWRAT as a result. The objectives of this project are therefore to:

- Review the deliverables of Microplastics 1.
- Establish the scale of microplastics present in highway runoff.
- Investigate the influence of factors on microplastics in highway runoff.
- Identify and contextualise contaminants including new contaminants of concern.

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[2] This is due to changes in methods and increases in evidence base by the Environment Agency in 2019, which makes the assessment not comparable to previous years. Four groups of global pollutants being assessed (polybrominated diphenyl ethers (PBDEs - a group of brominated flame retardants); Mercury; certain Polycyclic aromatic hydrocarbons (PAHs) and Perfluorooctane sulfonate (PFOS) a group of per - and polyfluoroalkyl substances (PFAS)) are causing the failure. There is little change in chemical status for chemicals which aren’t in these groups.

- Explore the benefits and options of reviewing and supplementing the dataset that underpins design and assessment tools such as HEWRAT.

- Make recommendations on further R&D and / or changes to current policy in DMRB or in existing Highways England management practices.

This is a joint project undertaken by Atkins and Jacobs, with the University of Plymouth sub-contracted to undertake the field sampling and laboratory analysis.

To undertake these objectives three key tasks have been undertaken:

1. The literature review from Phase 1 was updated to ensure it is as up to date as possible. The original literature review was undertaken by Atkins and Jacobs, and the update was also undertaken by Atkins and Jacobs. This Supplementary Literature Review has already been published (Highways England, 2021), and should be read in conjunction with the original literature review (Highways England, 2020).
2. Sampling and analysis for microplastics and tyre wear particles (TWPs) on the SRN to determine their scale and presence and the influence of certain factors. Additional sampling for contaminants including contaminants of concern in runoff was also undertaken as part of this task to feed into Task 3. This sampling and analysis was undertaken by the University of Plymouth, and the results are set out in Appendix AA.
3. A review of the current DMRB guidance and analysis of contaminants and microplastics data from the SRN to determine if the current tools adequately manage the pollution risk from microplastics and chemicals of concern. This review was undertaken by Jacobs, using results from the sampling and analysis for contaminants of concern from the University of Plymouth (Task 2), and the results are set out in Appendix B.

Individual reports set out the methodologies and findings for each of the three tasks listed above. Task 1 (the supplementary literature review) is already published and available (Highways England, 2021). Appendix A provides the full report from the ‘Quantifying Tyre Wear Particles and other Microplastics from the Strategic Road Network’ report, and Appendix B provides the full report from the ‘Initial assessment to identify future contaminants of concern’ report

This final report pulls together the key findings from this project and summarises them in order to: understand the scale of issues and key factors related to microplastics (and contaminants of concern) in the context of the SRN and National Highways statutory responsibility to not pollute the water environment; provide a review of the dataset underpinning HEWRAT and to determine if LA 113/CG 501 would need adapting; and, to identify, and provide costs for, future relevant research.

This report is set out as follows:

- Section 3 Key Findings – this section uses the key findings from the project to answer the objectives set out above.

- Section 4 Summary – this section pulls together the key findings from all of the tasks and summarises them.

- Appendix A – this section provides the full report from the ‘Quantifying Tyre Wear Particles and other Microplastics from the Strategic Road Network’ report.

- Appendix B – this section provides the full report from the ‘Exploration of Benefits and Options of Reviewing and Supporting Existing Datasets’ report.

- Appendix C – this section provides the detailed recommendations for future research and development ideas.

3. Key Findings

This section answers the key objectives of this project, as set out previously, namely:

- Review the deliverables of Microplastics Phase 1.
- Establish the scale of microplastics presence in highway runoff.
- Investigate the influence of factors on microplastics in highway runoff.
- Identify and contextualise contaminants including new contaminants of concern.
- Explore the benefits and options of reviewing and supplementing the dataset that underpins design and assessment tools such as HEWRAT.
- Make recommendations on further R&D and / or changes to current policy in DMRB or in existing Highways England management practices.

3.1. Review of Microplastics Phase 1 deliverables

A list of contaminants of concern was identified during Phase 1 of this project (Highways England, 2020). This list was reviewed and updated through consultation with the Project Steering Group (PSG) including the Environment Agency, the client (Mike Whitehead / National Highways) and the Consultant (Atkins and Jacobs), prior to the field sampling and laboratory analysis. Following review of the contaminants identified during Phase 1, and consultation with commercial laboratories, the following updates to the analysis list were made:

- BOD removed – due to the potential lag in sample collection leading to instability.
- 2-benzothiazolesulfenamide removed – not available at a commercial laboratory.
- Steranes replaced with stearic acid.
- Extended monitoring of Perfluorooctanoic acid (PFOA) and Perfluorooctane sulfonate (PFOS) to include a wider per- and polyfluoroalkyl substances (PFAS) suite – as requested by the EA.
- Included a full acid herbicides suite – as requested by the EA.
- Replaced mineral oil with speciated Total Petroleum Hydrocarbons (TPH) – as requested by the EA.

A literature review was undertaken during Phase 1 of the project to assess the potential contribution from the SRN of microplastics pollution in the water environment (Highways England, 2021). Part of the aim of this work was to direct a programme of monitoring. Phase 2 of research commenced in 2021, which included a supplementary literature review building upon that undertaken in Phase 1. Only key data or information and significant updates from the new literature gathered (since January 2020 when the last literature search was undertaken) were provided in this Phase of the literature review. The supplementary literature review should be read in conjunction with the original literature review published as part of Phase 1 (Highways England, 2020).

Key findings from the supplementary literature review are below.

3.1.1. Sampling and analysis methods

- Although it is well established through research that the dominant source of microplastic pollution from roads is tyre and road wear particles (TRWP), quantifying the sources with standardised analytical techniques is still a challenge.
- Further analytical techniques have been reported on since the last literature review, including the use of a Laser Direct Infrared (LDIR) analyser (an infrared imaging microscope, which is faster than using the traditional FTIR spectroscopes) and organic tyre constituents as markers in analysis, highlighting this as a leading-edge area of research.
- A growing body of research is also highlighting the most appropriate methods, and considerations to be taken, for sampling microplastics, as well as more studies which have sampled microplastics from the SRN in locations including drains, road dust and soils adjacent to roads. The sampling methods identified include:
    - Sampling from drain sumps / gully pots to collect road runoff.
    - Sampling a range of sediments / road runoff / roadside soil / road dust.
    - Sampling at various locations to represent different road / traffic conditions.
    - Sampling before and after any treatment systems.
    - Having a control location nearby.
    - Sampling under different antecedent conditions, and during conditions known to trigger runoff.
- Some further analytical techniques which help to determine microplastics derived from the SRN, as opposed to other sources, have been reported on, including their higher density and the ability to analyse for paint fragments.
- These sampling and analytical developments, as well as the understood need for standardisation across research studies, will help to focus future research most appropriately when SRN-derived microplastics are the objective of the study.

3.1.2. Contribution of the SRN to microplastics in the water environment

- The literature shows that information on the fate of microplastics when they enter the environment is limited, with further research into the role of rivers in transport and degradation of TRWPs needed.
- Additionally, there is a call for further detailed investigation into the various traffic and road factors which can influence microplastic pollution from roads.
- It is also recognised in the literature that the current techniques used for capturing and retaining sediment (e.g. stormwater ponds / SuDS basins) are suitable for TRWP associated microplastics, and should be retrofitted where possible, with regular maintenance for drainage systems implemented too.
- It has been demonstrated that the impacts of microplastics on ecosystems and human health are not clear and further research is needed.

3.2. The scale of microplastics presence in highway runoff

Tyre wear particles (TWPs) and other forms of microplastics (MPs) were quantified by Pyrolysis–gas chromatography–mass spectrometry (Py-GCMS) and Fourier-transform infrared spectroscopy (FTIR) respectively in drainage from highway runoff. The key findings from the sampling and analysis, to understand the scale of microplastics presence in highway runoff are below.

- TWPs were present in every environmental sample examined (70/70). Other microplastics were present in all but one sample (69/70).

- TWPs contributed between 0.081 and 6.14 % of the total solid mass within each sample (1.4 % ± 0.21).

- TWPs and TSS content were significantly correlated but more study is recommended prior to TSS being adapted as a proxy for tyre wear.

- Concentrations of TWPs reported in this study were at the lower end of the ranges previously reported in the literature. Table 3.2.1, largely adapted from Wik and Dave (2009), compares the range in measured and estimated concentrations of TWPs reported in surface water runoff, motorway pond sediments, motorway pond water and also in freshwater and freshwater sediments across the present and previous studies. Where the study quantified the concentration of a tyre wear marker but did not convert into an estimated mass of TWPs, Wik and Dave (2009) converted using reported concentrations of markers within tyre tread. Studies from Wik and Dave (2009) are marked with an asterisk(*). Direct comparisons between the studies in Table 3.2.1 should be made with caution due to a lack of standardised approaches, the variety of markers employed and potential sources of chemical markers to the environment other than tyre tread

Table 3.2.1: Comparisons of concentrations of tyre wear in the present study compared with that reported in previous studies.

Environmental matrix		Concentration	Marker	Region	Study
Water	Surface water runoff [mg/L]	2.5	BT	UK	Parker-Jurd *et al*. (2021)
		2.8 (0.01 - 28.9)	***BT***	***UK***	***This study***
		12	24MoBT	Japan	*Kumata *et al.* (2002)
		87	HOBT	USA	*Reddy and Quinn (1997)
		92	24MoBT	USA	*Zeng *et al.* (2004)
		93	24MoBT	Japan	*Kumata *et al.* (1997)
		97	BT	Germany	*Baumann and Ismeier (1998)
		179	24MoBT	Japan	*Kumata *et al.* (2002)
	Motorway drainage pond water [mg/L]	2.3	24MoBT	USA	*Reddy and Quinn (1997)
		0.46 (0.01 - 3.6)	***BT***	***UK***	***This study***
	River water [mg/L]	0.5	24MoBT	China	*Ni *et al*. (2008)
		1.6	24MoBT	USA	*Reddy and Quinn (1997)
		3.6	NCBA	Japan	*Kumata *et al.* (2000)
Sediment	Motorway drainage pond sediments [mg/g]	0.35	24MoBT	USA	*Reddy and Quinn (1997)
		3.7 - 20 mg/g	Zn	Germany	Klöckner *et al.* (2020)
		3.8 (0.2 - 12.5)	***BT***	***UK***	***This study***
	(motorway sediment basin)	360 - 480 mg/g	Zn	Germany	Klöckner *et al*. (2020)
	Sediments (river, lake estuary) [mg/g]	0.4	HOBT	USA	*Reddy and Quinn (1997)
		3.9	24MoBT	Japan	*Kumata *et al.* (2002)
		11	Extr. Org. Zn	Sweden	*Wik *et al.* (2008)
		155	24MoBT	USA	*Spies *et al.* (1987)
		40	Zn	Germany	Klöckner *et al.* (2020)

Data presented as averages; ranges are given in brackets where available. Data largely adapted from Wik and Dave (2009) showing measured and estimated concentrations of TWPs in surface water runoff, motorway pond and sediment basin sediments, settling pond water, river water and sediments, using a variety of chemical markers. BT = benzothiazole, 24MoBT = 2-(4- morpholinyl)benzothiazole, NCBA = N-cyclohexyl-2-benzothiazolamine, Zn = zinc, HOBT = 2-hydroxybenzothiazole.

- Concentrations of other microplastics typically sat within ranges previously reported in the literature, see Table 3.2.2. It is worth noting that these studies will vary in their sample collection, their means of isolating and analysing particles and in their detection limits, therefore it is not appropriate to directly compare reported concentrations. Variations in the abundance of microplastics across all these studies will also vary with population and other characteristics of the drainage area and river catchments.

Table 3.2.2: Comparisons of concentrations of other microplastics found within present study with existing literature.

Environmental matrix	Concentration	Region	Study
Drainage pond influent [MP/L]			
(Bioretention basin)	0.8	USA	Boni *et al*. (2022)
(Wetland)	0.9	Australia	Ziajahromi *et al.* (2020)
(Rain garden)	1.6	USA	Gilbreath *et al.* (2019)
	1.9	USA	Werbowski *et al.* (2021)
	5.98 (0.87 - 22.5)	***UK***	***This study***
Motorway pond effluent [MP/L]			
(Rain garden)	0.16	USA	Gilbreath *et al*. (2019)
(Rain garden)	0.7	USA	Werbowski *et al.* (2021)
	2.32 (0.42 - 7.83)	***UK***	***This study***
(Wetland)	4	Australia	Ziajahromi *et al.* (2020)
(Retention pond, collected during dry weather)	270	Denmark	Olesen *et al.* (2019)
Stormwater runoff [MP/L]	0.3 - 0.37	USA	Boni *et al*. (2022)
	3.1 (0.66 - 8.52)	***UK***	***This study***
	12 to 2054	Mexico	Piñon-Colin *et al.* 2020
Stormwater sampled after mixing with receiving waters [MP/L]	1.1 - 24.6	USA	Werbowski *et al.* (2021)
	2.3 - 29.4	Canada	Grbić *et al.* (2020)
Pond sediments [MP/kg]	320 - 595	Australia	Ziajahromi *et al.* (2020)
	4220 (0 - 14290)	***UK***	***This study***
	17490 (1511 - 127,986)	Denmark	Liu *et al*. (2019)

- The most commonly identified polymers among other microplastics in runoff from the SRN were polypropylene, polyethylene terephthalate, polyamide, acrylic, co-polymers, polyester, and polyurethane.

- While fibres were the dominant form of other microplastics, fragments represented around 40 % of the particles within direct runoff from the SRN.

- A study conducted in the same region as the majority of sites in the present study, non-tidal freshwaters in Devon and Cornwall, found fragments contribute on average only half as much to the total (20%, collected between 2020 – 2022 (personal communication)), further indicating that the breakdown of intentional or unintentional litter on highways contributes to microplastic loads from the SRN.

- Of the 93 synthetic particles within effluent from wetland and retention ponds, fibres account for the majority, followed by fragments and spheres. The estimated mass of TWPs was considerably greater than that of other microplastics in both runoff from the SRN and in pond sediments; this was agreeable with desk-based estimates suggesting TWPs contribute a substantial portion of total microplastic emissions to the natural environment.

3.3. The influence of factors on microplastics in highway runoff

As part of the sampling of highway runoff, samples were collected from curved and straight sections of the SRN, and in the influent and effluent of two types of drainage management systems (wetlands and retention ponds). The key findings from the sampling and analysis, to understand the influence of these different factors upon microplastics within highway runoff are below.

3.3.1. Curved and straight sections of the SRN:

- Surface water drainage from curved and straight sections of the road network contained between 0.01 and 3.21 mg of TWPs per litre.

- The mass of TWPs was on average 40 % greater in drainage from curved sections of the SRN (0.77 mg/L ± 0.38) compared with straight sections (0.47 ± 0.37) but this pattern was not statistically significant due to variation between sites.

- Direct drainage from curved and straight sections of the road network contained other microplastics in concentrations of between 0.66 and 8.52 particles per litre. No significant difference was observed in concentrations of other microplastics between road type (curve or straight).

3.3.2. Wetlands and retention ponds:

- Comparison of the concentration of TWPs and other microplastics between the influent and effluent of both wetlands and retention ponds found that for 10 of the 12 comparisons the highway drainage system assessed led to a reduction in the concentration of TWPs and other microplastics released to waterbodies when compared to the influent.

- Removal of other microplastics by both wetlands and retention ponds was highly variable ranging between 0 % and 98.1 % in efficiency.

- Wetland influent contained on average 5.6 mg/L ± 1.92 of TWPs and effluent 0.71 mg/L ± 0.38 of TWPs, yet this difference was not statistically significant.

- On average wetlands removed 72.6 % ± 14.5 of tyre wear but their performance varied by site 13.6 – 99.7 %.

- Retention pond influent contained on average 4.1 mg/L ± 3.22 of TWPs and effluent contained significantly less at 0.22 mg/L ± 0.13 of TWPs.

- Retention ponds removed on average 77.2 % ± 7.4 of tyre wear (38.4 – 99.9 %).

- Wetland and retention ponds sediment contained on average 3.83 mg/g or 3832.9 mg/kg of TWP, several orders of magnitude greater than in pond water indicating TWPs are accumulating and therefore highway drainage ponds are effective at capturing TWPs.

- Retention ponds and wetlands typically removed 56 % ± 42.5 of TSS.

- Wetland influent contained on average 5.6 ± 0.9 other microplastics a litre, and effluent 3 MP/L ± 0.8, this difference was not significant.

- On average wetlands removed 36.5 % ± 15.7 of other microplastics, on 3 occasions microplastic concentrations were greater in the pond effluent than the influent.

- Retention pond influent contained on average 6.4 MP/L ± 2.3 other microplastics, while effluent contained 1.6 MP/L ± 0.3 but this was not significant.

- Retention ponds removed on average 42.7 % ± 16.4 of other microplastics, on one occasion microplastic concentrations were greater in the pond effluent than the influent.

- After passing via wetlands and retention ponds, the mass of both TWPs and other forms of microplastics being released to aquatic waters in pond effluent were similar, suggesting TWPs were more effectively retained by wetlands and retention ponds than other forms of microplastics (Figure 3.1).

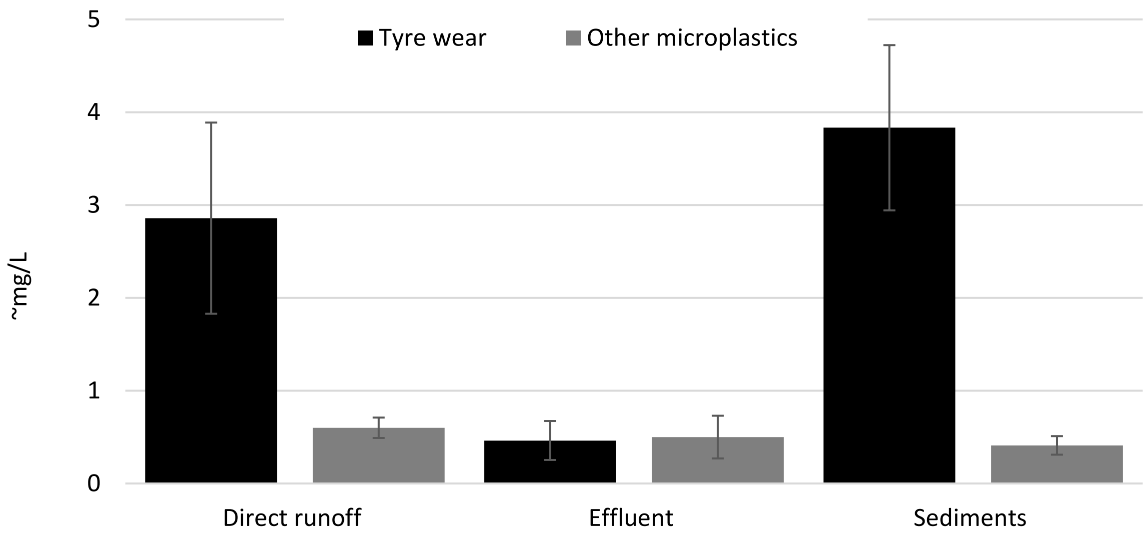

Figure 3.1: The relative mass of tyre wear (mg/L or mg/g) vs. the estimated relative mass of other microplastics (mg/L or mg/g) within direct drainage, pond effluent and pond sediments.

3.4. Identification and contextualisation of contaminants including new contaminants of concern

- The study was completed on a very limited number of samples and a wider and more thorough sampling study should be conducted to collect more robust data to inform decisions by National Highways. However, some early insights have been identified for contaminants of concern.

- A wide range of contaminants have been sampled within road runoff, of the 42 contaminants which were present in concentrations greater than the LOD, 30 of these contaminants have an established EQS / PNEC and 13 of these were found to be present in concentrations greater than the associated EQS / PNEC values (Table 3.4.1). Six other contaminants also had positive samples, but the mean concentrations were below LOD values. Based on this limited dataset these contaminants should be considered worthy of further investigation as they have the potential to be at concentrations of concern in road runoff.

- Other potential contaminants of concern have been highlighted but further research is needed to identify the risk to the aquatic systems that their presence in road runoff may have.

- Contaminants detected above the LOD in multiple samples have been presented in (Table 3.4.1). The contaminants that have not been investigated in previous National Highways runoff research undertaken by WRC (*Moy et al., 2003*), the availability of an EQS or PNEC and if the average concentrations exceed this standard are also presented. This list can be used to identify contaminants that are “new” to National Highways runoff research and if they have been detected in concentrations above the relevant standard.

Table 3.4.1 Contaminants worthy of further investigation

Contaminant	Included in WRc report?	Has an EQS/PNEC?	Average concentration > EQS/PNEC?
1,3-diphenylguanidine (DPG)	No	Yes	Yes
4-tert-octylphenol	No	Yes	Yes
Benzo(b)fluoranthene	Yes	Yes	Yes
Benzo(ghi)perylene	Yes	Yes	Yes
Chrysene	No	Yes	Yes
*Dibenzo(ah)anthracene**	*No*	*Yes*	*Yes*
Dissolved Copper	Yes	Yes	Yes
Dissolved Zinc	Yes	Yes	Yes
Fluoranthene	No	Yes	Yes
*PFOS**	*No*	*Yes*	*Yes*
Pyrene	No	Yes	Yes
Total Antimony	No	Yes	Yes
Total Copper	Yes	Yes	Yes
Total Manganese	No	Yes	Yes
Total Zinc	Yes	Yes	Yes
1-indanone	No	No	N/A
2-methylthiobenzothiazole	No	No	N/A
6:2 FTS	No	No	N/A
Benzo(a)anthracene	No	No	N/A
Benzo(bk)fluoranthene	No	No	N/A
Benzothiazole-2-sulfonic acid (BTSA)	No	No	N/A
Cyclohexyl-3-phenylurea (CPU)	No	No	N/A
Cyclohexylamine	No	No	N/A
Hexa(methoxymethyl)melamine	No	No	N/A
Hydroxybenzothiazole	No	No	N/A
Mercury Total by CVAF	No	No	N/A
N-(1,3-Dimethylbutyl)-N'-phenyl-p-phenylenediamine	No	No	N/A
N, N'-dicyclohexylurea (DHU)	No	No	N/A
Ortho Phosphate as P	No	No	N/A
PAH-16 Total	No	No	N/A

* Dibenzo(ah)anthracene and PFOS are included but there was a limited number of positive samples above LOD (4 and 1, respectively) – see Appendix B Table B.4. Further sampling with a lower LOD is required to better determine concern to the environment from these determinands.

- Analysis has shown a decreasing spread in contaminant concentrations as the amount of TWP increases. This could be due to the contaminants becoming bound to the TWPs and no longer soluble within the water samples. Further sampling and analysis is needed to understand this observation.

3.5. Benefits and options of reviewing and supplementing the dataset that underpins design and assessment tools such as HEWRAT

- In all instances in this study, using specific metrics for each outfall studies, HEWRAT was found to generate copper and zinc concentrations that are comparable to the sample data, however, a wider study would be beneficial to analyse the robustness of this claim.

- It is recommended that HEWRAT be updated to be housed in a digital user environment to improve user experience, efficiency, and ability to work collaboratively, better localised rainfall data, and to help with future updates and changes to regulations.

3.6. Recommendations on further R&D and / or changes to current policy in DMRB or in existing Highways England management practices

Recommendations that have come out of the three key tasks of this project are summarised below.

Supplementary literature review:

- Need for standardised sampling and analysis techniques for TWP and other microplastics.

- Greater understanding on the transport and degradation of TRWPs in rivers.

- Greater understanding of different traffic and road factors which influence microplastics from the SRN.

- Research into the impacts of microplastics on ecosystems and human health.

Sampling and analysis for microplastics and TWPs on the SRN:

- More regular cleaning and maintenance of roadside litter to reduce the amounts of other microplastics entering the drainage network.

- Further research to examine the efficacy of highway drainage systems under a variety of rainfall events and antecedent conditions before and after maintenance in order to better understand the variability introduced by these factors.

- Further work to examine the extent to which the following features might increase the efficacy of these assets in retaining microplastics a) cleaning or dredging assets more often to minimise resuspension of trapped particles; b) creating larger ponds with longer flow paths; and c) increasing the height of the pond effluent drain in order to increase residence time.

- Investigating what permutations of tyre tread design influence wear rates.

- Investigating the influence of pond design features, potential drivers in the performance of the highway drainage systems.

- Further examining the suitability of TSS to be used as a proxy for TWPs.

- Further studies to incorporate increased replication at a greater range of spatial and temporal scales.

- A more detailed examination into relative importance of the effects of influencing of factors such as driving style and vehicle maintenance by choosing study sites that receive drainage from areas including features such as junctions, roundabouts, or a mix of land uses would also prove insightful.

Exploration of benefits and options of reviewing and supporting existing datasets:

- This work has highlighted the need for future research to provide confidence in the conclusions and recommendations made.

- Further research is also necessary to improve understanding of the risk of the presence and prevalence of different contaminants, and how these interact with the aquatic ecosystem both in the short and long-term and how they interact with each to increase toxicity on the aquatic ecosystem through in-combination or cumulative effects.

These recommendations have been collated together to identify key areas for further research. These are grouped under the general themes of:

- Desk based studies.

- Field based studies.

- Policy / guidance.

Further details on these recommended areas for key research are provided in Appendix C.

Completion of these three tasks has identified that there are gaps where additional research is needed to fully understand the issue of TWP, other microplastics and contaminants of concern from the SRN.

4. Summary

This project confirms the presence of TWP and other microplastics in road runoff from the SRN, due to this being an emerging area of research, these contaminants have not been previously investigated by National Highways. The scale of TWP from the SRN was found to be at the lower end of the ranges in published literature, whereas other microplastics were typically within ranges previously reported. These findings highlight the scale of the issue and confirm that the SRN is an important source of TWP and that polymers identified across this study have a wide range of applications. To reduce these sources would require research into atmospheric microplastics, research by vehicle manufacturers into unintentional littering (e.g. degradation of car parts) as well as a review of litter management practices around the SRN. This project did not set out to understand whether TWP and other microplastics are present in quantities that are of concern. This would require an understanding of the hazard posed to both human and ecological health. In terms of contaminants of concern, 13 were present in concentrations greater than standards. As most of these are consistently present with TWPs, it would suggest that they originate from the same source, or tyres have contributed to the contamination. However, further sampling and analysis is needed to increase confidence in the conclusions, including further sampling in locations where types and usage of highways are similar. This supports the idea that contaminants can adhere to TWPs therefore further understanding of the mobilisation of TWPs and conditions for release of contaminants remains an area for further investigation.

In terms of National Highways existing guidance and standards, the research has highlighted that wetlands and ponds are more effective at capturing and retaining TWP than other microplastics. The removal ranges are in line with established removal efficiencies for dissolved copper, dissolved zinc and suspended solids. It is therefore recommended that National Highways should continue to prioritise these highway drainage systems in their design practices. The statistically significant correlation between TWPs and TSS content is promising; however, further study is recommended prior to TSS being adopted as a proxy for tyre wear. This finding has potentially important implications for the HEWRAT tool being able to adequately assess the risk for TWP and incorporating the risk in existing management practices for the retention of sediments. However, the relationship with other microplastics was not statistically significant and therefore may require a different approach.

Water samples collected for a small number of sites for contaminants of concern in road runoff align with copper and zinc concentrations generated by HEWRAT. This gives confidence that the current National Highways tool remains fit for purpose, although a wider study designed specifically for this purpose would be beneficial to analyse the robustness of this claim. The research has moved forward National Highways understanding of the chemical footprint of road runoff from the SRN however 13 contaminants of concern were identified that were present in concentrations greater than the associated EQS / PNEC values. Further investigations would be required to understand if the current guidance and tools are appropriate to actively manage these risks.

The knowledge gaps identified during this research into TWP, other microplastics and contaminants of concern reflect the emerging nature of these pollutants. Amongst the greatest implications of this for existing guidance for National Highways include the absence of standards. Standards are required to clarify the presence and prevalence of contaminants and their potential to be hazardous in aquatic ecosystems individually and in combination.

The focus for National Highways research should be to undertake further detailed investigation into which factors influence the generation of TWP, other microplastics and contaminants of concern from the SRN. This should be supported by research to understand the ultimate fate of TWP and other microplastics including ecotoxicological studies. A review of the existing maintenance programme for roadside litter and road drainage systems is also recommended. As the estimated mass of TWPs was considerably greater than that of other microplastics in both pond sediments and runoff from the SRN, it may be advisable for National Highways to engage with tyre manufactures to support an investigation into how tyre tread design can influence wear rates.

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Appendix A. Quantifying Tyre Wear Particles and other Microplastics from the Strategic Road Network

Appendix B. Exploration of Benefits and Options of Reviewing and Supporting Existing Datasets

Appendix C. Recommendations for future research and development areas

Completion of these three tasks has identified that there are gaps where additional research is needed to fully understand the issue of TWP, other microplastics and contaminants of concern from the SRN.

It is also beneficial to identify other stakeholders in these research areas, including, for example, academia, regulators, sampling/analysis providers (crudely, “labs”), the tyre/ motor industry and commercial providers of treatment solutions. Stakeholders might also include producers of road marking materials and road surfacing contractors. To consider the potential role of these stakeholders in future research, a responsibility assignment matrix, also known as RACI (Responsible, Accountable, Consulted, Informed) matrix, has been adapted and modified to help define potential participation or possible collaboration in the research. This modified RACI matrix is defined Table 3.6.1 below:

Table 3.6.1 RACI matrix

	Definition
Responsible **(R)**	Undertakes the research
Accountable **(A)**	Reviews and approves the research
Consulted **(C)**	Provides input to research based on either how it will impact their organisation or domain of expertise
Informed **(I)**	Needs to be kept abreast of ‘developments’ in the research without any direct input

Table 3.6.2 sets out the key areas for further research and Table 3.6.3 groups research packages into proposed projects.

Table 3.6.2 Key areas for further research

	Source (Appendix #)	Key future research & development area	Potential research activities	Desired outcomes	Key stakeholders	NH capacity to influence research input and outcomes
	Microplastics					
1		Development of standardised sampling and analytical methods	Analytical and sampling standardisation	This would provide a consistent approach and permit direct comparison of results with other studies	Academics (R? C, I) Commercial and research labs (R?, C) Environment Agency (R, A) Defra (R, A) Tyre industry (C, I)	Consulted / Informed
2		Research into traffic derived microplastic concentrations in soil	Field based monitoring of soils	Broaden microplastic monitoring alongside the SRN as this is lacking in current published literature	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I) Tyre industry (C, I)	Responsible Accountable
3		Develop an understanding of the ultimate fate of microplastics (and other contaminants of concern) generated from road surfaces (e.g. within the downstream water environment or other displacement from the network) and the impacts on ecosystems and human health	Field based monitoring of microplastic fate and behaviour Ecotoxicology studies of microplastics derived from TRWP and other contaminants of concern	Establish direct link between SRN microplastic mobilisation, transportation and potential impact in receiving waters, sediments and biota	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I) Tyre industry (C, I)	Responsible Accountable
4	A	Further understanding of how site characteristics (road type (high traffic versus low traffic), road surface material, driving style, type of vehicles (HGV versus passenger cars), traffic conditions (high speed travel versus increased intermitted breaking), composition of tyre material (optimisation of reducing wear without comprising safety) and / or vehicle maintenance) influence the generation of microplastics from the SRN and its distribution in the drainage network	Field based monitoring for a range of site characteristics Quantitative study on the SRN	Broaden microplastic monitoring as this is lacking in current published literature. Determine if particular site characteristics dictate generation of microplastics pollution Prompt potential change in NH assessment and design guidance	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I) Tyre industry (C, I) Commercial treatment enterprises (I)	Responsible Accountable
5		Review existing sites for implementation of treatment / mitigation systems for the entrapment / treatment of microplastics and retrofitting where appropriate	Desk based review SRN treatment / mitigation systems	Identification of sites for installation / retrofitting of treatment / mitigation systems	Environment Agency (C, I) Defra (C, I)	Responsible Accountable
6		Define suitable maintenance programme for road drainage systems and implement it across the SRN	Frequency, removal techniques and disposal of microplastics	Minimising downstream transport of microplastics from the SRN	Environment Agency (C, I) Defra (C, I)	Responsible Accountable
7	A	Further sampling of runoff, with increased replication at a greater range of spatial and temporal scales	Field based monitoring and lab analysis	Better inform actions to reduce and intercept microplastics from the SRN	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I) Tyre industry (C, I) Commercial treatment enterprises (I)	Responsible Accountable
8	A	More regular cleaning and maintenance of roadside litter	Field based monitoring and implementation of cleaning and maintenance regimes	Reducing the rate at which microplastics are generated by fragmentation of larger waste	Environment Agency (C, I) Defra (C, I)	Responsible Accountable
9	A	Evaluate how different features of retention ponds may increase the efficiency of these assets in retaining microplastics a) cleaning or dredging assets more often to minimise resuspension of trapped particles; b) creating larger ponds with longer flow paths; and c) increasing the height of the pond effluent drain in order to increase residence time	Field based monitoring	Optimising design of retention ponds to increase efficiency of microplastic retention	Environment Agency (C, I) Defra (C, I)	Responsible Accountable
10	A	Investigate the influence of pond design features as potential drivers in the performance of the highway drainage systems for reducing concentrations of suspended tyre particles and other microplastics	Field based monitoring of different ponds	Optimising the design of ponds to increase reduction of suspended tyre particles and other microplastics	Environment Agency (C, I) Defra (C, I)	Responsible Accountable

	Source (Appendix #)	Key future research & development area	Potential research activities	Desired outcomes	Key stakeholders	NH capacity to influence research input and outcomes
11	A	Evaluate the efficacy of HE drainage and treatment / mitigation systems and standards (including SuDS systems) in the entrapment / treatment of microplastics (and their capacity for subsequent remobilisation) under a variety of rainfall events and antecedent conditions before and after maintenance	Evaluation of different measures to treat / contain / mitigate microplastics in relation to rainfall events antecedent conditions and maintenance Compare with existing measures / guidance to contain sediments and maintenance guidance. Undertake field trials?	Determine whether different conditions (rainfall, antecedent conditions, maintenance regimes) affect the ability for current measures to contain and treat sediments for microplastics (including retention and propensity for re- mobilisation)	Academics (C, I) Environment Agency (C) Commercial treatment enterprises (C)	Responsible Accountable
12	A	Investigate the use of TSS concentrations in runoff as a proxy for tyre particles	Field based monitoring of runoff	This would determine if TSS in runoff, which is cheaper and more easily quantified, can be used as a proxy for tyre particles in runoff	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I) Tyre industry (C, I)	Consulted / Informed
13	A	Investigate what permutations of tyre tread design influence wear rates	Lab-based investigation	Determine optimum tyre design to minimise particulate release	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I) Tyre industry (C, I)	Consulted / Informed
	Contaminants of concern					
14	B	A robust dataset is lacking to assess whether NH policy needs updating for chemicals of potential concern	Identification of research baseline via literature review and Phase 2 monitoring for a targeted list of pollutants	Establishes current academic understanding	Environment Agency (C) Defra (A)	Responsible Accountable
15			Focused investigation and monitoring of pollutants of potential concern (water and sediment) in road runoff to build on the preliminary findings from Phase 2 monitoring	Builds on literature review findings and existing monitoring to provide robust evidence of whether NH policy changes are justified	Environment Agency (C) Defra (A)	Responsible Accountable
16	B	Develop EQS / PNEC values for contaminants that are commonly present within runoff samples	Development of PNEC and / or PNEC's to benchmark SRN runoff	Improved understanding of whether contaminants are of concern to the environment or human health	Academics (C) Commercial and research labs (I) Environment Agency (C, I)	Consulted / Informed
17	B	Develop / identify / source analytical techniques with lower limits of detection for contaminants of potential concern where LOD's are > EQS or PNEC	Identify if commercial labs can meet required LOD's and where necessary develop appropriate analytical methods	Detection of contaminants to assess against EQS / PNEC	Commercial and research labs (I) Environment Agency (C, I)	Consulted / Informed
18	B	Further understanding of how site characteristics (road type (high traffic versus low traffic, dilution effects) influence the contaminant concentrations from the SRN	Identification of research baseline via literature review	Identification of research baseline via literature review Determine if particular site characteristics dictate generation of microplastics pollution	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I)	Responsible Accountable
19			Field based monitoring for a range of site characteristics potential including rain gauge installation at sampling locations	Broaden contaminant monitoring as this is lacking in current published literature Prompt potential change in NH assessment and design guidance	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I)	Responsible Accountable
20	B	Gather a robust dataset to assess the relationship between microplastics (tyre particles), and other contaminants commonly found in road runoff	Field and or lab-based experiments to relationships	Robust dataset to assess for statistical significance	Academics (C) Commercial and research labs (I) Environment Agency (C, I) Defra (C, I)	Consulted / Informed

	Source (Appendix #)	Key future research & development area	Potential research activities	Desired outcomes	Key stakeholders	NH capacity to influence research input and outcomes
21	B	Update to HEWRAT to an online digital user environment	Update capabilities for general user updates and updates to contaminant reference data, better localised rainfall data	NH to be able to interrogate and understand usage of the tool for future updates		Responsible Accountable

Table 3.6.3 Research project proposals – identification and prioritization

	Proposed Project	Potential research packages	NH responsible or accountable?	Potential influence on NH policy and / or guidance	Timescale of benefit to NH	Indicative NH budget	NH Priority/rank
Item (s) from Table 6.2	**Microplastics**						
1	Development of standardised sampling and analytical methods	Working group Analytical and sampling standardisation	No	Indirect - regarding use of standard methods in field studies	< 3 years	n/a	n/a
2	Research into traffic derived microplastic concentrations in soil	Desk based literature review Field based monitoring of soils	Yes	Indirect – widens understanding of receptors for SRN derived microplastics	0-5 years	£20K Literature review £50K upwards field sampling depending on the scale of monitoring	=4
3	Understanding of the ultimate fate of microplastics	Desk based literature review Ecotoxicology studies of microplastics derived from TRWP Field based monitoring of microplastic fate and behaviour	Yes	Direct - could steer future guidance and policy	0-5 years	£20K Literature review £50K upwards for ecotox studies Field trials £100k upwards depending on the scale of monitoring (To be combined with item 16 costs identified separately)	=2
4, 7, 12	Further detailed investigation into which factors influence the generation of microplastics from the SRN	Desk based literature review Field based monitoring for a range of site characteristics / temporal and spatial scales Quantitative study on the SRN Investigate TSS concentrations as a proxy for tyre particles	Yes	Direct - could steer future guidance and policy	0-5 years	£20K Literature review Field trials £200K- 250K, depending on potential for collaboration (To be combined with item 14, 15, 18, 19 costs identified separately)	=1
6, 8	Define suitable maintenance programme for roadside litter and road drainage systems	Frequency, removal techniques and disposal of microplastics Field based monitoring and implementation of cleaning and maintenance regimes	Yes	Direct – highway maintenance regimes	0-2 years	£10K- £50K	=2
5, 9, 10, 11	Review existing sites for entrapment / treatment of microplastics Investigate design of retention ponds to optimise design for microplastic retention	Desk based review SRN treatment / mitigation systems Field based monitoring Evaluation of different measures to treat / contain / mitigate microplastics in relation to rainfall	Yes	Direct – CG 501 guidance	0-3 years	Desk study £30K- £50K Field trials £200K- 250K, depending on potential for collaboration	3

	Proposed Project	Potential research packages	NH responsible or accountable?	Potential influence on NH policy and / or guidance	Timescale of benefit to NH	Indicative NH budget	NH Priority/rank
	Research how they behave under a range of rainfall conditions	events antecedent conditions and maintenance. Compare with existing measures / guidance to contain sediments and maintenance guidance Undertake field trials?					
13	Investigate what permutations of tyre tread design influence wear rates	Focused literature / desk study Consultation with tyre manufacturers Lab-based investigation	No	No	n/a	n/a	n/a
	Contaminants of concern						
3	Understanding of the ultimate fate of contaminants of concern	Ecotoxicology studies of contaminants of concern	Yes	Direct - could steer future guidance and policy	0-5 years	£50K upwards for ecotox studies	5
14, 15, 18, 19	Further detailed investigation into which factors influence contaminants of concern	Identification of research into contaminants of concern and potentially influencing site characteristics via a literature review Monitoring for a targeted list of pollutants (water and sediment)	Yes	Direct - could steer future guidance and policy	0-5 years	£50K upwards depending on the scale of monitoring To be integrated with Microplastics studies. (To be combined with item 4, 7, 12 costs identified separately)	=1
16	Develop EQS / PNEC values for contaminants that are commonly present within runoff samples	Derive EQS / PNEC using ecotoxicological studies	No	Direct - could steer future guidance and policy	0-5 years	n/a? (To be combined with item 3 costs identified separately)	n/a
17	Develop / identify / source analytical techniques with lower limits of detection for contaminants of potential concern where LOD's are > EQS or PNEC	Review commercial labs LOD's If necessary, identify contaminants for which lower LOD's are required Industry wide assessment of cost benefit to develop lower LOD's	Yes?	Direct e.g. if leads to revised EQS	0-2 years	£50K upwards for ecotox studies	=4
20	Gather a robust dataset to assess the relationship between microplastics (tyre particles), and other contaminants commonly found in road runoff	Focused literature / desk study Field and or lab trials Consultation with tyre manufacturers	Yes	Indirect	0-5 years	£20K Literature review Field trials £100k upwards depending on the scale of monitoring	=4
21	Update to HEWRAT to an online digital user environment	Consultation with user group Review of reference data Create online digital interface	Yes	Indirect	0-2 years	£10K- £20K	5