Tyre Pollution in the UK's Rivers: Evenlode Case Study

The frightening chemical soup leaching from our tyres and running off our roads

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Executive summary

An adequate supply of fresh, clean water is essential for all life on our planet. Yet, in the UK, our freshwater ecosystems are in a state of alarming decline, damaged by pollution from sewage, agriculture and roads. The extent of this degradation has been partially hidden by incomplete or missing data. Citizen science offers a powerful tool to address this gap.

In 2024, Earthwatch Europe, in collaboration with Emissions Analytics, and with the help of citizen scientists began a project to understand the impact of tyre particulate matter on the water quality of two important tributaries of the Thames: the Evenlode and the Windrush rivers. In January 2025, Earthwatch, working with Emissions Analytics and the Evenlode Catchment Partnership, developed this research and demonstrated, unequivocally, that chemicals from tyres are entering our freshwater system – mapping their journey from road to river.

Across our road networks, surface water run-off washes into local rivers each time it rains. Roadway run-off flows through storm drains and into storm sewers or combined sewers where it commonly enters our freshwater environments without treatment. In England alone, there are more than 18,000 outfalls associated with the motorways and roads with **more than a million local highway drains discharging directly to watercourses[1].**

Citizen scientists collected samples of water from standing water on the roads, following rain events, as well as from outfalls to the rivers, and then in the receiving rivers, beneath outfalls as well as both up – and down-stream of outfalls. Analysis showed more than 900 unique organic (meaning chemically carbon-based) compounds present in samples over a single weekend. Though the chemical concoctions differ between locations, **every single river site tested contained a mix of chemicals known to be toxic to aquatic life.**

It is clear that the increasing focus being put on this topic by the Environment Agency and National Highways needs to be backed by the necessary funding to understand and address this pressing issue; for authorities to integrate citizen science into their freshwater monitoring frameworks; and for citizen scientists to continue monitoring and advocating for their rivers.

We want to see data-driven change to ensure that our future rivers are healthy from source to sea.

Key findings

- In this report we build the evidence base for which compounds are found in tyres and which of them travel from road to river
- **995 unique organic chemical compounds** were detected across all samples
- **Eleven novel tyre compounds** – never clearly evidenced before in the literature as coming from tyres – were detected across all locations
- The chemical compositions polluting the Evenlode differ between locations; but all contain a mix of chemicals known to be **toxic** to aquatic life; those with the potential to **bioaccumulate**; and those which are known **carcinogens**
- Most chemicals analysed for this report were found within rivers at concentrations that could pose risk to aquatic life according to the NORMAN Ecotoxicology Database
- We are particularly concerned by the levels of methylene chloride and n-hexane – two toxic chemicals – running from roads to rivers across this catchment

Thank You

This study would not have been possible without the support of the Evenlode Catchment Partnership, Emissions Analytics or the citizen scientists who collected the water samples to be analysed.

Urban run-off and tyre wear pollution

Urban run-off is the surface water that results from rainwater in urban areas. Urban run-off flows over impervious surfaces – such as road surfaces, paved streets, car parks, and building rooftops – into sewer systems to be treated at wastewater facilities, or directly into freshwater systems through drainage culverts. The term 'urban run-off' also covers run-off from roads in rural and semi-rural areas.

Tyre wear pollution is a serious growing environmental problem and is being exacerbated by the increasing popularity of large, heavy passenger vehicles and the number of heavy goods vehicles on the roads. Unlike exhaust emissions which are being addressed by car makers thanks to the pressure placed on them by European emissions standards, tyre wear pollution is largely unregulated, with only eight PAHs (polycyclic aromatic hydrocarbons) commonly found in extender oils subject to a limit value under REACH (Registration, Evaluation, Authorisation, and Restriction of Chemicals). New cars now generate less particulate matter in their exhaust, but there is growing concern around 'non-exhaust emissions'.

Non-exhaust emissions are particles released from brake wear, tyre wear, road surface wear and resuspension of road dust during on-road vehicle usage. While regulatory progress is being made – with some legislation in place to limit or reduce these emissions – much of it is yet to come into effect, and in the meantime these emissions are causing a great deal of concern for both air and water quality.

What's in a tyre?

The British Tyre Manufacturing Association states that truck tyres typically contain 30% natural rubber, and car tyres contain about 15%. Tyres are made up of 42% elastomers (both natural and man-made rubber material), 28% carbon black and silica, 12% steel, 6% oils, 5% textile, 1% zinc oxide, 1% sulphur and 5% other ingredients.

Results

Citizen scientists collected water samples across nine locations in the Evenlode catchment. Samples were collected in triplicate at five sites per location: (1) puddles on the road; (2) water flowing from outfalls into the river; (3) the river directly beneath the outfall; (4) upstream out the outfall; and (5) downstream of the outfall. (Figure 1).

Across the samples collected by citizen scientists and analysed by Emissions Analytics, **995 unique compounds** were detected. Of these 995 volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs), 592 are in Emissions Analytics' tyre database, and 41 of these are cited in the literature – which is limited and with many knowledge gaps – as being found in tyres. These 41 known tyre compounds can be grouped as shown in Table 1.

Volatile organic compounds (VOCs) are organic chemicals that have a significant vapour pressure at room temperature. If they are allowed to build up in the air, they can harm human health or damage the environment. VOCs come from many different classes of chemicals, including alcohols and acids[2].

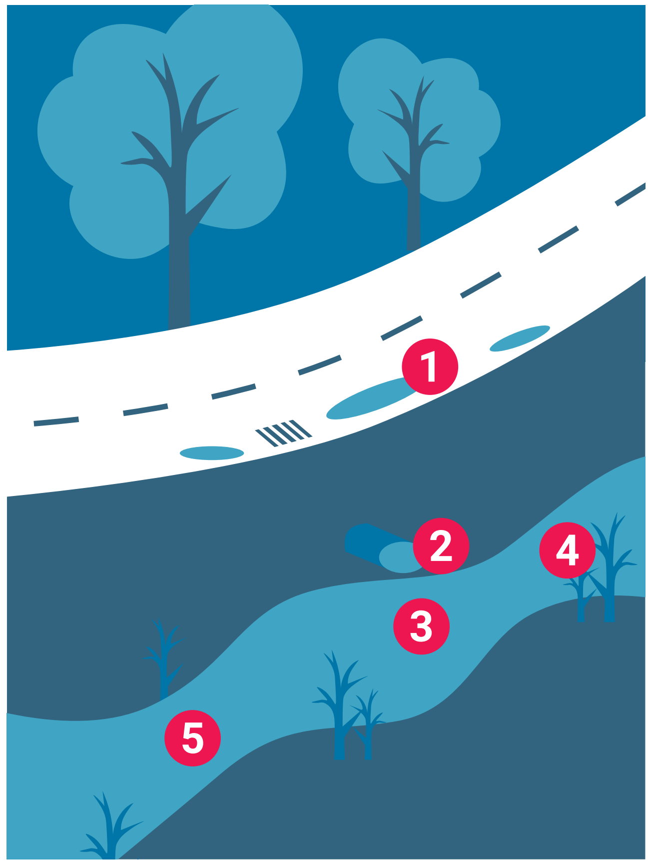


Figure 1. Sampling sites from road to river.

Group	Chemicals in group
Known tyre additive – vulcanisation process	1
Known tyre additive – other	1
Natural rubber derived (including hydrogenated)	2
Styrene-butadiene rubber derived	5
Extender oil derived	5
Other polymer (PP, PS, PMMA, PET, PC, PVC, PE)	1
Previously unidentified chemical/ additive or a pyrolysis product	26

Table 1. Categories of 41 known tyre compounds detected across samples.

Styrene-butadiene rubber derived compounds are synthetic rubbers developed by tyre manufacturers. **Extender oils** help improve the processability of rubber, and function as a lubricant, helping to make it easier and faster to manufacture tyres. Extender oils are produced from mineral oils. Untreated and mildly treated mineral oils are **known to be human carcinogens** based on sufficient evidence of carcinogenicity from studies in humans. Though their concentrations are restricted in tyres because of this, **they are not banned.**

For the remaining 551 unique compounds in Emissions Analytics' tyre database there is no evidence in the literature to confirm whether or not they are in tyres. However, of the 551, 29 appear when the original tyres are gently heated and the gases that evaporate from the surface analysed; a process called "off-gassing". In total, therefore, we are confident **70 of the unique compounds detected are from tyres.**

We wanted to be able to investigate the movement of unique compounds from road to river. We therefore looked at the most frequently detected compounds; those that were most likely to appear in samples, regardless of site. **Twenty-four unique compounds** were detected **at least 20 times** across all samples (Table 2).

Compound	Frequency	Literature	Database	Off-Gassing
Benzene, 1,3-bis(1,1-dimethylethyl)-	141	X	X	X
Methylene chloride	83	X	✓	X
Nonadecane	76	X	✓	✓
2,4-Di-tert-butylphenol	76	X	X	X
Hexadecane	64	X	✓	✓
n-Hexane	59	X	X	✓
Tetradecane	48	X	✓	✓
1H-Indene, 2,3-dihydro-1,1,3-trimethyl-3-phenyl-	45	X	X	X
1-Octadecyne	36	X	X	✓
Heptadecane	35	X	✓	X
1-Octanol, 2-butyl-	34	X	X	X
Oxirane, tetradecyl-	33	X	X	X
Octadecane, 1-(ethenyloxy)-	31	X	X	X
Undecane	29	X	✓	✓
9,12-Octadecadienoyl chloride, (Z,Z)-	28	X	X	X
Benzene, 1,1'-[1,2-ethanediylbis(oxy)]bis-	27	X	X	X
9,12-Octadecadienoic acid (Z,Z)-	26	X	X	X
Caryophyllene oxide	25	X	X	X
Tridecane	25	X	✓	✓
Benzene, tert-butyl-	22	X	X	X
cis-11-Hexadecenal	21	X	X	X
Phytol	21	X	✓	✓
Parthenolide	20	X	✓	✓
Acenaphthene	20	✓	✓	✓

Table 2. Compounds detected at least 20 times: blue were selected for further analysis.

Of the 24 unique compounds detected more than 20 times, 13 were selected for further analysis across samples. **Acenaphthene** is an extender oil, cited in the literature as being a known tyre compound. In this sense, it acts as a 'tracer' – demonstrating that the methods are suitable for investigating tyre particulate matter.

Eleven of these compounds have not been studied in the literature, but we have evidence to suggest they are tyre chemicals, including through off-gassing experiments: methylene chloride, nonadecane, hexadecane, n-hexane, tetradecane, 1-octadecyne, heptadecane, undecane, tridecane, phytol and parthenolide. We consider these to be **novel tyre compounds.** A final compound, **benzene, 1,3-bis(1,1-dimethylethyl)** – was also selected for investigation, despite not appearing in the literature, database or off-gassing, due to it being **the most frequently detected** chemical.

Chemicals of interest[3] – Red chemicals are known to be potentially toxic

Benzene, 1,3-bis(1,1-dimethylethyl) – as reported in our pilot study, is an alkylbenzene. The toxicity of alkylbenzenes has been found to be relatively low. However, in high concentrations they might pose significant risks to humans and the environment.

Methylene chloride is a colourless, volatile liquid with a chloroform-like smell, widely used as a solvent. The Environmental Protection Agency considers methylene chloride to be a probable human carcinogen.

Nonadecane is a component of petroleum products and may be released into the environment through the processing and combustion of petroleum products containing this chemical. Although not considered toxic, the potential for **bioconcentration** in aquatic organisms – the process by which an organism absorbs and accumulates chemicals from its environment – is high.

Hexadecane is not classified as hazardous to the aquatic environment, but it has a very high potential to **bioaccumulate**; the process by which substances build up in organisms over time.

n-Hexane is a colourless liquid made from crude oil. If n-Hexane is spilled into a lake or river, a very small portion will dissolve in the water, but most will float on the surface and evaporate into the air. n-Hexane is toxic to aquatic organisms with long-lasting effects.

Tetradecane is a straight chain alkane. It is not classified as an acutely toxic substance, but it has high potential for **bioconcentration**.

1-Octadecyne toxicological properties have **not been fully investigated.**

Heptadecane is a known component in petroleum products. It is not classified as toxic, but the potential for **bioconcentration** in aquatic organisms is high.

Undecane is found in crude oil. It is not classified as acutely toxic, although at high enough concentrations it has been shown to have tumour – promoting activity.

Tridecane appears as an oily, straw yellow clear liquid. It is not classified as toxic, but the potential for **bioconcentration** in aquatic organisms is high.

Phytol is an alcohol. It is **very toxic** to aquatic life with long-lasting effects.

Parthenolide is an ester; a combination of an acid and an alcohol. At high enough concentrations it is suspected of causing genetic defects.

Acenaphthene is one of a group of chemicals called polycyclic aromatic hydrocarbons, (PAH). PAHs are created when products like coal, oil, gas, and garbage are burned but the burning process is not complete. Acenaphthene is **very toxic** to aquatic life with long-lasting effects. In the life cycle toxicity test with acenaphthene, hatchability of the midge was affected by 50% at an exposure concentration of approximately 0.17 mg/L.

Mapping tyre pollution across the Evenlode

68 unique compounds (from Emissions Analytics' tyre database) were detected across **downstream** samples (Figure 2). Eleven of our compounds of interest are detected in downstream samples: ten novel tyre compounds and benzene, 1,3-bis(1,1-dimethylethyl)-. Acenaphthene and parthenolide are not detected in downstream samples.

Figure 2 suggests that the specific **chemical composition between downstream samples at different locations greatly varies.** For example, Chipping Norton had the fewest unique compounds in downstream samples (five), whereas Cassington had the most unique compounds detected in downstream samples (36).

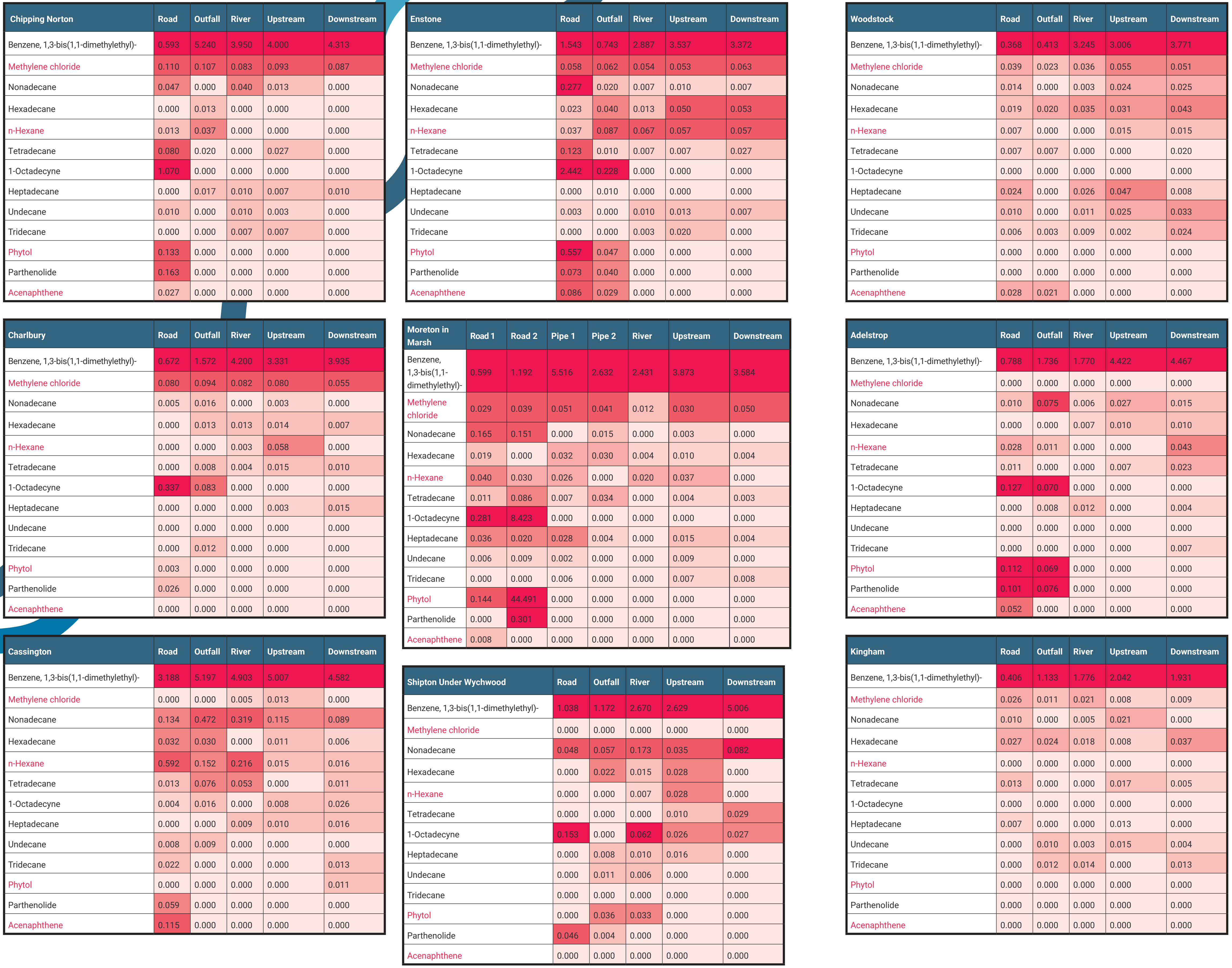
We hypothesise that the variation between locations could be due to several factors relating to vehicles, the surrounding landscape and the waterbodies. It is possible that the predominant vehicles on roads adjacent to waterbodies differ between locations; more heavy goods vehicles in one location, more cars in another, for example. Road surface maintenance and speed limits could also differ between sites, impacting tyre wear. The distance from road to waterbody and the speed at which water travels from the road to the watercourse – impacted by the topography of the area – might affect the presence of chemicals; as could the volume of water travelling from road to watercourse, and the river flow itself. Finally, it is possible that some locations may have non-tyre sources of these chemicals.

We can further compare the concoctions of chemicals polluting the Evenlode catchment across locations, looking at each site from road to river (Figure 3).

	Chipping Norton	Charlbury	Cassington	Enstone	Moreton-in-Marsh	Shipton Under Wychwood	Woodstock	Adelstrop	Kingham
Benzene, 1,3-bis(1,1-dimethylethyl)-	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
2,4-Di-tert-butylphenol	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
Methylene chloride	🟥	🟥		🟥	🟥		🟥		🟥
Hexadecane		🟥	🟥	🟥	🟥		🟥	🟥	🟥
Nonadecane			🟥	🟥		🟥	🟥	🟥	
Tetradecane		🟥	🟥	🟥	🟥	🟥	🟥	🟥	🟥
n-Hexane			🟥	🟥			🟥	🟥	
Tridecane			🟥		🟥		🟥	🟥	🟥
Heptadecane	🟥	🟥	🟥		🟥		🟥	🟥	
Acetone				🟥	🟥		🟥		🟥
1-Octadecyne			🟥			🟥			
Undecane				🟥			🟥		
Isopropyl Alcohol				🟥			🟥		
1-Tetradecene			🟥			🟥			
Benzene, 1,1'-[1,2-ethanediylbis(oxy)]bis-			🟥			🟥		🟥	
Heptacosane						🟥		🟥	
10-Undecen-1-ol			🟥			🟥			
1-Hexadecanol			🟥			🟥			
Decane, 2-methyl-			🟥	🟥					
2',4'-Dimethoxyacetophenone			🟥			🟥			
1-Octanol, 2-butyl-			🟥						
17-Pentatriacontene			🟥						
Phytol			🟥						
Octadecane, 1-(ethenyloxy)-			🟥			🟥			
Benzene, 1,4-bis(1,1-dimethylethyl)-			🟥						🟥
1,10-Decanediol						🟥			
Dodecane							🟥		
1H-Indene, 2,3-dihydro-1,1,5-trimethyl-									🟥
4,6-di-tert-Butyl-m-cresol									🟥
Pentadecane	🟥								
Hexane, 2,2,5-trimethyl-		🟥							
1,4-Methanobenzocyclodecene, 1,2,3,4,4a,5,8,9,12,12a-decahydro-			🟥						
Gamabufotalin			🟥						
Heneicosane, 11-(1-ethylpropyl)-			🟥						
Propanedioic acid			🟥						
Tetradecanoic acid, 3,3a,4,6a,7,8,9,10,10a,10b-decahydro-3a,10a-dihydroxy-5-(hydroxymethyl)-2,10-dimethyl-3-oxobenz[e]azulen-8-yl ester, [3aR-(3aα,6aα,8α,10β,10aβ,10bβ)]-			🟥						
1,14-Tetradecanediol			🟥						
Tetradecane, 1-chloro-			🟥						
Ethanol, 2-(dodecyloxy)-			🟥						

	Chipping Norton	Charlbury	Cassington	Enstone	Moreton-in-Marsh	Shipton Under Wychwood	Woodstock	Adelstrop	Kingham
Eicosane, 3-methyl-			🟥						
Octadecane, 3-ethyl-5-(2-ethylbutyl)-			🟥						
1-Dodecanol, 3,7,11-trimethyl-			🟥						
Heptadecane, 9-hexyl-			🟥						
tert-Hexadecanethiol			🟥						
Butanimidamide, N-(1-chloro-2-methyl-1-butenyl)-2-methyl-			🟥						
Cyclohexane, 1,1'-dodecylidenebis[4-methyl-			🟥						
Pentane, 2-methyl-			🟥						
1,12-Dichlorododecane				🟥					
Decane				🟥					
1,4-Cyclohexanedimethanol				🟥					
Heptane					🟥				
Undecane, 2,6-dimethyl-					🟥				
Octane, 4-ethyl-					🟥				
Cetene						🟥			
Oxirane, octyl-						🟥			
Phenol, 3,5-bis(1,1-dimethylethyl)-						🟥			
1,12-Dodecanediol						🟥			
1-Hexanol, 5-methyl-2-(1-methylethyl)-						🟥			
1,3-Cyclooctadiene						🟥			
Ethanone, 1-(3,4-dimethoxyphenyl)-						🟥			
Pendimethalin						🟥			
Octane, 2,6-dimethyl-								🟥	
Undecane, 2-methyl-									🟥
Cyclooctene, 4-methylene-6-(1-propenylidene)-									🟥
Naphthalene, 1,2,3,4-tetrahydro-1,5-dimethyl-									🟥
Hexane, 2,2,4-trimethyl-									🟥
2,6-Di-tert-butyl-4-hydroxy-4-methylcyclohexa-2,5-dien-1-one									🟥
Benzene, 1-(1-methylethenyl)-4-(1-methylethyl)-									🟥
Benzene, 1-(1-methylethenyl)-4-(1-methylethyl)-									🟥

Figure 2. Unique compounds across downstream samples. Chemicals of interest in blue.



Chipping Norton	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	0.593	5.240	3.950	4.000	4.313
Methylene chloride	0.110	0.107	0.083	0.093	0.087
Nonadecane	0.047	0.000	0.040	0.013	0.000
Hexadecane	0.000	0.013	0.000	0.000	0.000
n-Hexane	0.013	0.037	0.000	0.000	0.000
Tetradecane	0.080	0.020	0.000	0.027	0.000
1-Octadecyne	1.070	0.000	0.000	0.000	0.000
Heptadecane	0.000	0.017	0.010	0.007	0.010
Undecane	0.010	0.000	0.010	0.003	0.000
Tridecane	0.000	0.000	0.007	0.007	0.000
Phytol	0.133	0.000	0.000	0.000	0.000
Parthenolide	0.163	0.000	0.000	0.000	0.000
Acenaphthene	0.027	0.000	0.000	0.000	0.000

Charlbury	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	0.672	1.572	4.200	3.331	3.935
Methylene chloride	0.080	0.094	0.082	0.080	0.055
Nonadecane	0.005	0.016	0.000	0.003	0.000
Hexadecane	0.000	0.013	0.013	0.014	0.007
n-Hexane	0.000	0.000	0.003	0.058	0.000
Tetradecane	0.000	0.008	0.004	0.015	0.010
1-Octadecyne	0.337	0.083	0.000	0.000	0.000
Heptadecane	0.000	0.000	0.000	0.003	0.015
Undecane	0.000	0.000	0.000	0.000	0.000
Tridecane	0.000	0.012	0.000	0.000	0.000
Phytol	0.003	0.000	0.000	0.000	0.000
Parthenolide	0.026	0.000	0.000	0.000	0.000
Acenaphthene	0.000	0.000	0.000	0.000	0.000

Cassington	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	3.188	5.197	4.903	5.007	4.582
Methylene chloride	0.000	0.000	0.005	0.013	0.000
Nonadecane	0.134	0.472	0.319	0.115	0.089
Hexadecane	0.032	0.030	0.000	0.011	0.006
n-Hexane	0.592	0.152	0.216	0.015	0.016
Tetradecane	0.013	0.076	0.053	0.000	0.011
1-Octadecyne	0.004	0.016	0.000	0.008	0.026
Heptadecane	0.000	0.000	0.009	0.010	0.016
Undecane	0.008	0.009	0.000	0.000	0.000
Tridecane	0.022	0.000	0.000	0.000	0.013
Phytol	0.000	0.000	0.000	0.000	0.011
Parthenolide	0.059	0.000	0.000	0.000	0.000
Acenaphthene	0.115	0.000	0.000	0.000	0.000

Enstone	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	1.543	0.743	2.887	3.537	3.372
Methylene chloride	0.058	0.062	0.054	0.053	0.063
Nonadecane	0.277	0.020	0.007	0.010	0.007
Hexadecane	0.023	0.040	0.013	0.050	0.053
n-Hexane	0.037	0.087	0.067	0.057	0.057
Tetradecane	0.123	0.010	0.007	0.007	0.027
1-Octadecyne	2.442	0.228	0.000	0.000	0.000
Heptadecane	0.000	0.010	0.000	0.000	0.000
Undecane	0.003	0.000	0.010	0.013	0.007
Tridecane	0.000	0.000	0.003	0.020	0.000
Phytol	0.557	0.047	0.000	0.000	0.000
Parthenolide	0.073	0.040	0.000	0.000	0.000
Acenaphthene	0.086	0.029	0.000	0.000	0.000

Moreton in Marsh	Road 1	Road 2	Pipe 1	Pipe 2	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	0.599	1.192	5.516	2.632	2.431	3.873	3.584
Methylene chloride	0.029	0.039	0.051	0.041	0.012	0.030	0.050
Nonadecane	0.165	0.151	0.000	0.015	0.000	0.003	0.000
Hexadecane	0.019	0.000	0.032	0.030	0.004	0.010	0.004
n-Hexane	0.040	0.030	0.026	0.000	0.020	0.037	0.000
Tetradecane	0.011	0.086	0.007	0.034	0.000	0.004	0.003
1-Octadecyne	0.281	8.423	0.000	0.000	0.000	0.000	0.000
Heptadecane	0.036	0.020	0.028	0.004	0.000	0.015	0.004
Undecane	0.006	0.009	0.002	0.000	0.000	0.009	0.000
Tridecane	0.000	0.000	0.006	0.000	0.000	0.007	0.008
Phytol	0.144	44.491	0.000	0.000	0.000	0.000	0.000
Parthenolide	0.000	0.301	0.000	0.000	0.000	0.000	0.000
Acenaphthene	0.008	0.000	0.000	0.000	0.000	0.000	0.000

Shipton Under Wychwood	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	1.038	1.172	2.670	2.629	5.006
Methylene chloride	0.000	0.000	0.000	0.000	0.000
Nonadecane	0.048	0.057	0.173	0.035	0.082
Hexadecane	0.000	0.022	0.015	0.028	0.000
n-Hexane	0.000	0.000	0.007	0.028	0.000
Tetradecane	0.000	0.000	0.000	0.010	0.029
1-Octadecyne	0.153	0.000	0.062	0.026	0.027
Heptadecane	0.000	0.008	0.010	0.016	0.000
Undecane	0.000	0.011	0.006	0.000	0.000
Tridecane	0.000	0.000	0.000	0.000	0.000
Phytol	0.000	0.036	0.033	0.000	0.000
Parthenolide	0.046	0.004	0.000	0.000	0.000
Acenaphthene	0.000	0.000	0.000	0.000	0.000

Woodstock	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	0.368	0.413	3.245	3.006	3.771
Methylene chloride	0.039	0.023	0.036	0.055	0.051
Nonadecane	0.014	0.000	0.003	0.024	0.025
Hexadecane	0.019	0.020	0.035	0.031	0.043
n-Hexane	0.007	0.000	0.000	0.015	0.015
Tetradecane	0.007	0.007	0.000	0.000	0.020
1-Octadecyne	0.000	0.000	0.000	0.000	0.000
Heptadecane	0.024	0.000	0.026	0.047	0.008
Undecane	0.010	0.000	0.011	0.025	0.033
Tridecane	0.006	0.003	0.009	0.002	0.024
Phytol	0.000	0.000	0.000	0.000	0.000
Parthenolide	0.000	0.000	0.000	0.000	0.000
Acenaphthene	0.028	0.021	0.000	0.000	0.000

Adelstrop	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	0.788	1.736	1.770	4.422	4.467
Methylene chloride	0.000	0.000	0.000	0.000	0.000
Nonadecane	0.010	0.075	0.006	0.027	0.015
Hexadecane	0.000	0.000	0.007	0.010	0.010
n-Hexane	0.028	0.011	0.000	0.000	0.043
Tetradecane	0.011	0.000	0.000	0.007	0.023
1-Octadecyne	0.127	0.070	0.000	0.000	0.000
Heptadecane	0.000	0.008	0.012	0.000	0.004
Undecane	0.000	0.000	0.000	0.000	0.000
Tridecane	0.000	0.000	0.000	0.000	0.007
Phytol	0.112	0.069	0.000	0.000	0.000
Parthenolide	0.101	0.076	0.000	0.000	0.000
Acenaphthene	0.052	0.000	0.000	0.000	0.000

Kingham	Road	Outfall	River	Upstream	Downstream
Benzene, 1,3-bis(1,1-dimethylethyl)-	0.406	1.133	1.776	2.042	1.931
Methylene chloride	0.026	0.011	0.021	0.008	0.009
Nonadecane	0.010	0.000	0.005	0.021	0.000
Hexadecane	0.027	0.024	0.018	0.008	0.037
n-Hexane	0.000	0.000	0.000	0.000	0.000
Tetradecane	0.013	0.000	0.000	0.017	0.005
1-Octadecyne	0.000	0.000	0.000	0.000	0.000
Heptadecane	0.007	0.000	0.000	0.013	0.000
Undecane	0.000	0.010	0.003	0.015	0.004
Tridecane	0.000	0.012	0.014	0.000	0.013
Phytol	0.000	0.000	0.000	0.000	0.000
Parthenolide	0.000	0.000	0.000	0.000	0.000
Acenaphthene	0.000	0.000	0.000	0.000	0.000

Figure 3. Mapping pollution from road to river in locations across the Evenlode catchment. Tables are coloured with the same conditional formatting applied across locations, so chemical concentrations can be compared by location.

The location with the summed highest concentration of chemicals in river samples is Cassington, but we are particularly concerned by two toxic chemicals entering the freshwater system across multiple locations: **n-hexane** and **methylene chloride.**

The data in Figure 2 can also be displayed by chemical rather than location, to give a better idea of how individual chemicals behave across locations (Figure 4).

Chemicals behave in different ways. Benzene, 1,3-bis(1,1-dimethylethyl)-, for example, appears to accumulate in the river, with higher concentrations in the river (directly beneath the outfall, as well as upstream and downstream) compared to the road and outfall.

Some chemicals, such as methylene chloride, are found at consistent concentrations across sites. Others, for example, acenaphthene, are not detected in river samples, despite being present on the road and in the outfall. It is possible that these chemicals rapidly evaporate from water, or that any preventative measures to reduce particulate matter entering waterbodies are effective.

Intriguingly, some chemicals, like tridecane, are not typically found in road or outfall samples, but are found in river samples. It is difficult to explain this without further investigation; it is possible concentrations in road and pipe samples were too low to be detected, or that there are non-tyre sources of this chemical.

While we had anticipated to see greater differences between upstream and downstream samples, it is likely that the sheer number of sites where road run-off enters our waterways prevents us from being able to pinpoint pollution hotspots. Further analysis will also need to be undertaken for us to understand why some chemicals increase and others decrease in concentration from road to river.

Benzene, 1,3-bis(1,1-dimethylethyl)-	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.593	5.240	3.950	4.000	4.313
Charlbury	0.672	1.572	4.200	3.331	3.935
Cassington	3.188	5.197	4.903	5.007	4.582
Enstone	1.543	0.743	2.887	3.537	3.372
Moreton in Marsh	0.599	5.516	2.431	3.873	3.584
	1.192	2.632			
Shipton Under Wychwood	1.038	1.172	2.670	2.629	5.006
Woodstock	0.368	0.413	3.245	3.006	3.771
Adelstrop	0.788	1.736	1.770	4.422	4.467
Kingham	0.406	1.133	1.776	2.042	1.931

n-Hexane	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.013	0.037	0.000	0.000	0.000
Charlbury	0.000	0.000	0.003	0.058	0.000
Cassington	0.592	0.152	0.216	0.015	0.016
Enstone	0.037	0.087	0.067	0.057	0.057
Moreton in Marsh	0.040	0.026	0.020	0.037	0.000
	0.030	0.000			
Shipton Under Wychwood	0.000	0.000	0.007	0.028	0.000
Woodstock	0.007	0.000	0.000	0.015	0.015
Adelstrop	0.028	0.011	0.000	0.000	0.043
Kingham	0.000	0.000	0.000	0.000	0.000

Methylene chloride	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.110	0.107	0.083	0.093	0.087
Charlbury	0.080	0.094	0.082	0.080	0.055
Cassington	0.000	0.000	0.003	0.013	0.000
Enstone	0.058	0.062	0.054	0.053	0.063
Moreton in Marsh	0.029	0.051	0.012	0.030	0.050
	0.039	0.041			
Shipton Under Wychwood	0.000	0.000	0.000	0.000	0.000
Woodstock	0.039	0.023	0.036	0.055	0.051
Adelstrop	0.000	0.000	0.000	0.000	0.000
Kingham	0.026	0.011	0.021	0.008	0.009

Tetradecane	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.080	0.020	0.000	0.027	0.000
Charlbury	0.000	0.008	0.004	0.015	0.010
Cassington	0.013	0.076	0.053	0.000	0.011
Enstone	0.123	0.010	0.007	0.007	0.027
Moreton in Marsh	0.011	0.007	0.000	0.004	0.003
	0.086	0.034			
Shipton Under Wychwood	0.000	0.000	0.000	0.010	0.029
Woodstock	0.007	0.007	0.000	0.000	0.020
Adelstrop	0.011	0.000	0.000	0.007	0.023
Kingham	0.013	0.000	0.000	0.017	0.005

Nonadecane	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.047	0.000	0.040	0.013	0.000
Charlbury	0.005	0.016	0.000	0.003	0.000
Cassington	0.134	0.472	0.319	0.115	0.089
Enstone	0.277	0.020	0.007	0.010	0.007
Moreton in Marsh	0.165	0.000	0.000	0.003	0.000
	0.151	0.015			
Shipton Under Wychwood	0.048	0.057	0.173	0.035	0.082
Woodstock	0.014	0.000	0.003	0.024	0.025
Adelstrop	0.010	0.075	0.006	0.027	0.015
Kingham	0.010	0.000	0.005	0.021	0.000

1-Octadecyne	Road	Outfall	River	Upstream	Downstream
Chipping Norton	1.070	0.000	0.000	0.000	0.000
Charlbury	0.337	0.083	0.000	0.000	0.000
Cassington	0.004	0.016	0.000	0.008	0.026
Enstone	2.442	0.228	0.000	0.000	0.000
Moreton in Marsh	0.281	0.000	0.000	0.000	0.000
	8.423	0.000			
Shipton Under Wychwood	0.153	0.000	0.062	0.026	0.027
Woodstock	0.000	0.000	0.000	0.000	0.000
Adelstrop	0.127	0.070	0.000	0.000	0.000
Kingham	0.000	0.000	0.000	0.000	0.000

Hexadecane	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.000	0.013	0.000	0.000	0.000
Charlbury	0.000	0.013	0.013	0.014	0.007
Cassington	0.032	0.030	0.000	0.011	0.006
Enstone	0.023	0.040	0.013	0.050	0.053
Moreton in Marsh	0.019	0.032	0.004	0.010	0.004
	0.000	0.030			
Shipton Under Wychwood	0.000	0.022	0.015	0.028	0.000
Woodstock	0.019	0.020	0.035	0.031	0.043
Adelstrop	0.000	0.000	0.007	0.010	0.010
Kingham	0.027	0.024	0.018	0.008	0.037

Heptadecane	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.000	0.017	0.010	0.007	0.010
Charlbury	0.000	0.000	0.000	0.003	0.015
Cassington	0.000	0.000	0.009	0.010	0.016
Enstone	0.000	0.010	0.000	0.000	0.000
Moreton in Marsh	0.036	0.028	0.000	0.015	0.004
	0.020	0.004			
Shipton Under Wychwood	0.000	0.008	0.010	0.016	0.000
Woodstock	0.024	0.000	0.026	0.047	0.008
Adelstrop	0.000	0.008	0.012	0.000	0.004
Kingham	0.007	0.000	0.000	0.013	0.000

Undecane	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.010	0.000	0.010	0.003	0.000
Charlbury	0.000	0.000	0.000	0.000	0.000
Cassington	0.008	0.009	0.000	0.000	0.000
Enstone	0.003	0.000	0.010	0.013	0.007
Moreton in Marsh	0.006	0.002	0.000	0.009	0.000
	0.009	0.000			
Shipton Under Wychwood	0.000	0.011	0.006	0.000	0.000
Woodstock	0.010	0.000	0.011	0.025	0.033
Adelstrop	0.000	0.000	0.000	0.000	0.000
Kingham	0.000	0.010	0.003	0.015	0.004

Acenaphthene	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.027	0.000	0.000	0.000	0.000
Charlbury	0.000	0.000	0.000	0.000	0.000
Cassington	0.115	0.000	0.000	0.000	0.000
Enstone	0.086	0.029	0.000	0.000	0.000
Moreton in Marsh	0.010	0.000	0.000	0.000	0.000
	0.000	0.000			
Shipton Under Wychwood	0.000	0.000	0.000	0.000	0.000
Woodstock	0.028	0.021	0.000	0.000	0.000
Adelstrop	0.052	0.000	0.000	0.000	0.000
Kingham	0.000	0.000	0.000	0.000	0.000

Tridecane	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.000	0.000	0.007	0.007	0.000
Charlbury	0.000	0.012	0.000	0.000	0.000
Cassington	0.022	0.000	0.000	0.000	0.013
Enstone	0.000	0.000	0.003	0.020	0.000
Moreton in Marsh	0.000	0.006	0.000	0.007	0.008
	0.000	0.000			
Shipton Under Wychwood	0.000	0.000	0.000	0.000	0.000
Woodstock	0.006	0.003	0.009	0.002	0.024
Adelstrop	0.000	0.000	0.000	0.000	0.007
Kingham	0.000	0.012	0.014	0.000	0.013

Phytol	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.133	0.000	0.000	0.000	0.000
Charlbury	0.003	0.000	0.000	0.000	0.000
Cassington	0.000	0.000	0.000	0.000	0.011
Enstone	0.557	0.047	0.000	0.000	0.000
Moreton in Marsh	0.144	0.000	0.000	0.000	0.000
	44.491	0.000			
Shipton Under Wychwood	0.000	0.036	0.033	0.000	0.000
Woodstock	0.000	0.000	0.000	0.000	0.000
Adelstrop	0.112	0.069	0.000	0.000	0.000
Kingham	0.000	0.000	0.000	0.000	0.000

Parthenolide	Road	Outfall	River	Upstream	Downstream
Chipping Norton	0.163	0.000	0.000	0.000	0.000
Charlbury	0.026	0.000	0.000	0.000	0.000
Cassington	0.059	0.000	0.000	0.000	0.000
Enstone	0.073	0.040	0.000	0.000	0.000
Moreton in Marsh	0.000	0.000	0.000	0.000	0.000
	0.301	0.000			
Shipton Under Wychwood	0.046	0.004	0.000	0.000	0.000
Woodstock	0.000	0.000	0.000	0.000	0.000
Adelstrop	0.101	0.076	0.000	0.000	0.000
Kingham	0.000	0.000	0.000	0.000	0.000

Figure 4. Chemical heatmaps. Tables are coloured with conditional formatting applied per chemical, so chemical concentration can be mapped from road to river.

A note on drinking water

Reassuringly, VOCs can typically be treated and removed from water using a combination of **air sparging** – the injection of oxygen or air – **carbon filtration** – in which activated charcoal binds to the carbon in the chemical – and **reverse osmosis** – in which water is forced through a semi-permeable membrane to remove nearly all contaminants.

Nevertheless, in 2014 the Drinking Water Inspectorate investigated fourteen VOCs – including methylene chloride – to determine if exposure to these substances via drinking water poses a risk to human health and to provide guidance to water companies on the factors that may need to be considered in their risk assessments of VOCs. While the available literature data and the results of exposure modelling suggested that the concentrations of VOCs in drinking water are very low and are likely to be below those of health concern, the report highlighted several gaps within the data that limits the reliability of the model. Notably (1) a lack of information on the current **volumes of VOCs manufactured** and used within England and Wales, and (2) information on the **occurrence of these VOCs in the environment**[4].

A note on environmental toxicity

The NORMAN Ecotoxicology Database contains information on the Predicted No Effect Concentration (PNEC) of chemicals. Note that this is detailed in ug/L in the database, but has been expressed as ug/ml here, in line with concentrations detected in samples. As can be seen in Table 3, many of the compounds detected in the Evenlode are much higher than their PNEC.

Almost every chemical for which the PNEC is known that we analysed for this report is found within waterbodies at concentrations which **could pose some risk to aquatic life.** Exactly what these risks might be are yet to be determined.

Chemical	PNEC (ug/ml)	Detected in river at higher than PNEC
Benzene, 1,3-bis(1,1-dimethylethyl)-	Unknown	–
Methylene chloride	0.02	✓
Nonadecane	0.00001405	✓
Hexadecane	0.00003365	✓
n-Hexane	0.00193254	✓
Tetradecane	0.00008034	✓
1-Octadecyne	Unknown	–
Heptadecane	0.00002369	✓
Undecane	0.00015495	✓
Tridecane	0.00017879	✓
Phytol	0.00003485	✓
Parthenolide	Unknown	–
Acenaphthene	0.0037	X

Table 3. Chemicals, their predicted no effect concentration, and whether we detected them at concentrations higher than this across all samples. Red chemicals are toxic to aquatic life.

Where do we go from here?

In this study, we have evidenced on a small scale the concerning presence of tyre particle matter entering our rivers. There is much we can still learn from this study, and we will be publishing the full results in a peer-reviewed publication later this year.

The literature is far from comprehensive and there is much we don't yet know about this form of pollution. We don't know the precise chemical composition of tyres, nor every compound that might be emitted from tyre wear. We don't know how many of these chemicals make their way into rivers; and we don't know what their impacts on the aquatic environment are: individually, as they break down, in combination with each other, or in combination with the high levels of nutrients, antibiotics, fungicides and pesticides that enter our freshwater systems through sewage discharges and agricultural run-off.

This dataset – of 995 unique organic compounds – was collected over one weekend, at nine sites in one catchment. Multiply this across the million local highway drains discharging directly to watercourses every time it rains, and the sheer scale of the problem begins to emerge.

And, as we previously highlighted, the potential impact of these chemicals can be significant. In the United States, 6PPD-quinone – a product of the reaction in air of 6PPD, a chemical that prevents tyres from degrading – was shown to be the cause of **acute mortality events in salmon**, with toxicity induced at threshold concentrations of ~1ug/L[5] (or 0.001ug/ml). For comparison's sake, n-hexane, known to be toxic, and with a PNEC of 0.002ug/ml was found at 0.057ug/ml in the river at Cassington.

We may not have wiped out entire populations of aquatic organisms yet, but if tyre pollution continues to be released into our freshwater environments unregulated, the potential for acute mortality events will only increase.

Earthwatch Europe wants to see accountability from all types of polluters: from agriculture, sewage overflows and urban run-off.

As individuals, we can reduce tyre wear through optimised vehicle selection, vehicle maintenance and driving technique: for example, reducing harsh braking, rapid acceleration, and fast cornering, which tend to lead to increased emission levels due to high forces between the tyre and the road.

At the vehicle and road surface level, technological devices to capture tyre wear at the vehicle, road pavement as a trap for particulate matter, as well as street cleaning and dust binding to remove pollution are all possible mitigation measures that could be implemented.

For wider treatment of road run-off, we want to see the use of **nature-based solutions**; retention basins (artificial ponds with vegetation around the perimeter of a pool of water), detention basins (a structure into which stormwater run-off is directed, held for a period, and slowly drained to a surface waterbody) and constructed wetlands (a man-made basin that contains slowly-moving surface water, organic materials as well as water-tolerant plants, and organisms similar to those found in natural wetlands) can all trap suspended particles and improve water quality[6].

We urge National Highways to take action to reduce these emissions: enforcing speed limits and maintaining road surfaces, ensuring vehicle weights are lowered and high-quality tyres are fitted across the UK. We urge the Environment Agency to invest proper resources into monitoring tyre particle matter across the nation's freshwaters, for authorities to integrate citizen science into their freshwater monitoring frameworks, and for citizen scientists to continue monitoring and advocating for their rivers.

We thank our citizen scientists for making this research possible, and for continuing to fight for a healthy freshwater future.

Methods

Citizen scientists collected water samples across nine locations in the Evenlode catchment from the 23rd to 26th of January. Samples were collected in triplicate at five sites per location: (1) puddles on the road; (2) water flowing from outfalls into the river; (3) the river directly beneath the outfall; (4) upstream out the outfall; and (5) downstream of the outfall.

Emissions Analytics analysed the presence of compounds using solid-phase microextraction with two-dimensional Gas Chromatography-Mass Spectrometry.

Samples were extracted using the DVB/PDMS/Carbon WR Smart SPME fibre and desorbed on a GC injection. An Agilent 8890 Gas Chromatographer equipped with a Markes International Bench Time-of-Flight Mass Spectrometer (GCxGC-TOF-MS), using a flow modulator from SepSolve Analytical was used to analyse chemical concentration. The repeatability of measurements is typically reported as ±25% of the concentration values.

For analysis, triplicate samples were averaged and values were assigned a colour on a three-colour scale. Sample D3.3 was excluded from analysis due to outlier values.

Comparable air and water quality tests for organic chemical compounds can be purchased at **https://whatsinmy.world/.**

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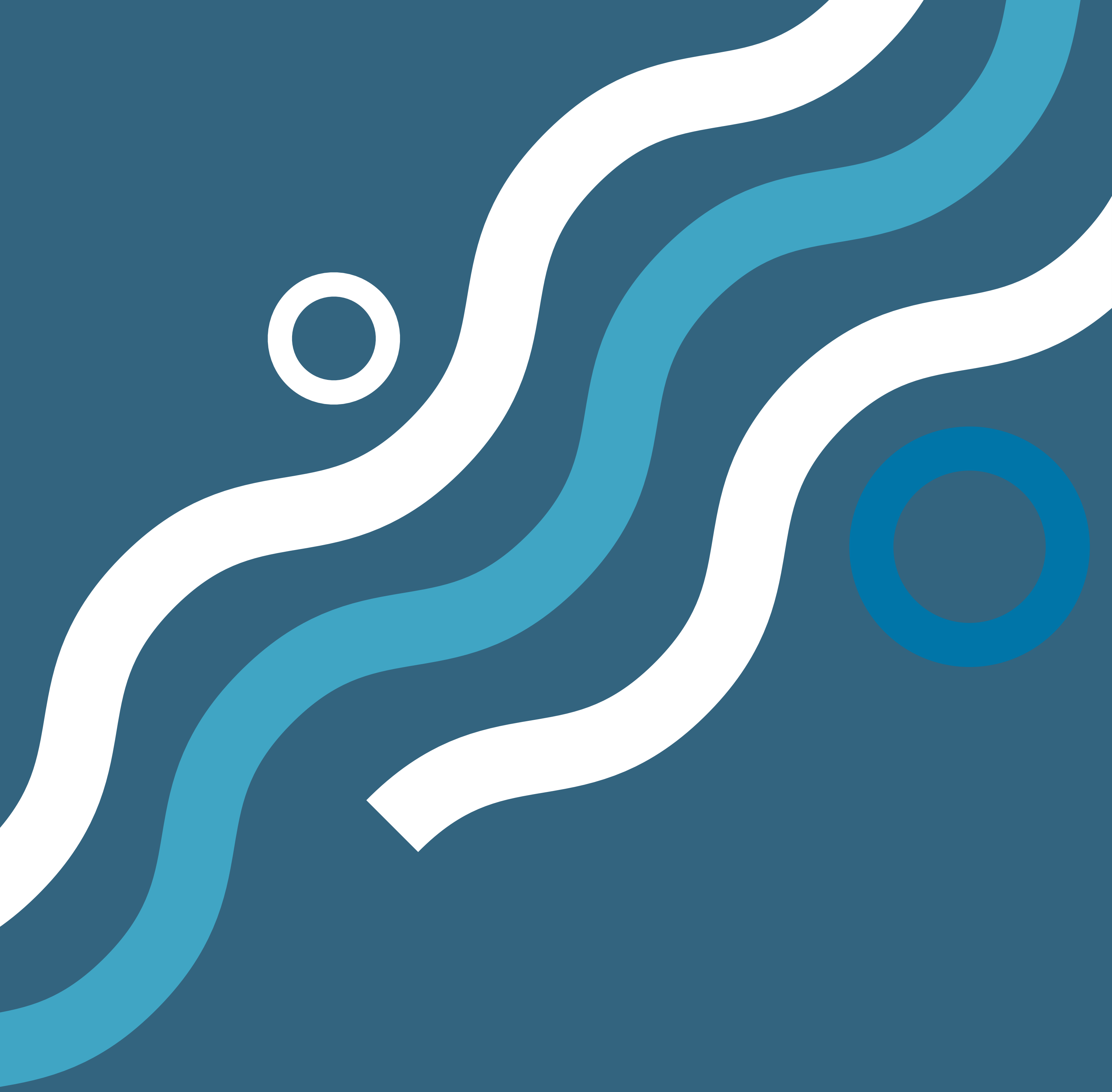

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