

The Role of Road Markings in Stormwater Runoff Contamination

1.0 Introduction

Road markings are not just decorative paint on the side of the road, but are essential for safe, efficient road networks and public safety. But as the inevitable wearing down of road markings takes place, what contaminants are released and what effects do these have on our wider environments and our health? And do they get considered in stormwater treatment train designs?

2.0 What are Road Markings Made Of?

The visibility of road markings differs with time of day and lighting; this creates different performance requirements that any one road marking must comply with. For example, in daytime hours, the colour of the road marking (typically white or yellow) must contrast with the colour of the road surface. However, with low light or low visibility conditions, for example at night, retro-reflectivity is needed to improve visibility for drivers. This reflectivity is achieved by the addition of glass microbeads.

A typical road marking contains a bottom coating layer- which provides the colour to the lines and a top retro-reflective layer- where glass microbeads are added. As the layers fade, road markings may be renewed to ensure effective functionality. The maximum height for a road marking to project above the surface of the adjacent road is 6mm. At this point, the road marking must be mechanically removed and entirely replaced.

There are many different types of road markings used globally. Generally, road markings include resins, reflectors and pigments. The type of each is dependent on traffic intensity, climate/ environmental aspects, available resources and equipment, costs and local/ national regulations. These factors will differ in specific countries, regions and sites but are important to factor in for the longevity of the road markings and critically the safety of road users.

Resins in road markings act as a durable binder-which acts as the glue of the formulation, holding all other components (reflectors, pigments and additives) together and ensuring the adhesion of the marking to the road surface. Different types of resins use include:

- Thermoplastics (hot melt markings): produce bright, highly visible markings with slow wear off rates. It is the most commonly used road marking in the UK and is classed as the standard.
- Solvent-based paints: produce low-medium durable markings which contain 25% VOCs.
- Water-based paints: markings are medium-high in durability and more environmentally friendly due to them containing less VOCs (<5%).
- Cold plastics materials (e.g. MMA resins): requires no heat during installations and are gaining popularity in the UK due to fast drying-time ensuring minimal traffic disruptions and quick work turn-over.
- Tape: adhesive tape that is easily applied and removed for temporary markings.

- Preformed materials: pre-cut shapes that get transported to site, heated and applied to road surfaces.

Reflectors are the use of glass microbeads within the top retro-reflective layer, which can also protect the bottom coating layer from abrasion. They can be premixed with the coating layer or dropped onto the surface immediately after application. With either technique the glass microbeads are only partially embedded in the paint, ensuring light is refracted and reflected from vehicles correctly.

Pigments are used to determine the colour of the road marking and additional fillers such as CaCO_3 can be used for extra friction, protection and reflectivity. These pigments/ fillers can be metal based.

3.0 Contaminants within Road Markings

Contaminants that are released from the abrasion of road markings vary depending on the type of materials used, but typically include microplastics, heavy metals and other toxic chemical additives.

3.1 Microplastics

Microplastics are defined as pieces of man-made polymers that are smaller than 5mm. They often don't break down quickly. They are omnipresent within our environments and can be classified as primary or secondary sourced microplastics. Primary sourced microplastics are intentionally added to products, while secondary sources include microplastics that are created when plastics are exposed to chemical and physical weathering which leads to their disintegration. In 2024 the European Union Road Federation categorised road marking paint into 'unintentional microplastics', with their initiatives only intending to reduce emissions of 'intentional microplastic emissions', therefore not addressing the microplastic contamination derived from road markings.

Thermoplastic resins are more likely to be a high source of microplastics because they are designed to wear off and expose new glass microbeads. Once released from road markings, microplastics can be washed into and transported via stormwater runoff. this widens their distribution and so the impacts of the microplastics.

3.2 Heavy Metal Elements

Heavy metals are released from the abrasion of road markings (mainly from yellow markings) due to the pigments and reflectors used in their formulations. Lead (Pb) is used in road markings to stabilise the colour, inhibit corrosion, reduce drying times and act as a fungicide. Chromium (Cr (VII)) can be found with lead in the form of lead chromate (PbCrO_4). Lead chromate was a commonly used pigment until restrictions were put in place once research identified their effects. It was though still legal to use PbCrO_4 in the production of road markings in the EU until May 2019. In research studies PbCrO_4 is now used as a tracer for older markings that pre-date these restrictions. White road marking pigments include titanium dioxide (TiO_2) and zinc oxide (ZnO), with Barium sulphate (BaSO_4) used as a filler to improve wear resistance of the road marking. This creates the potential of releasing the heavy metals titanium, zinc or barium into the natural environment.

There are many other chemical additives that are used as decolourisers, stabilisers, plasticisers, curing agents or refining agents in the production of road markings. These could potentially release various heavy metal elements into the environment.

When heavy metals are released from road markings, they preferentially bind to the finer particles, sized less than 64µm (PM64). This allows adsorption to take place more readily because of their large surface area to mass ratio. Fine particles are more likely to be entrained within the flow of stormwater and urban runoff as they are lightweight and have low settling velocities. In traditional drainage systems, stormwater runoff is transported as quickly as possible away from a site to a receiving water body. Little to no treatment of the runoff is taken place in these systems, meaning all the contaminants (including heavy metals) that are picked up from road surfaces in the runoff are transported within the stormwater runoff.

3.3 Volatile Organic Compounds

VOCs are released from the application of road markings as well as during their service life when they are abraded. Solvent-based paint road markings are the primary emitters of VOCs as 25% of their resins are VOCs content. They are organic compounds that are commonly found present in stormwater runoff from various sources. VOCs are found in high concentrations in the dissolved phase but do also associate with suspended sediments in stormwater runoff- typically fine particles or organic matter. If dissolved, they are more mobile in the flow of water. These chemicals are resistant to degradation and are able to be transported long distances once released from road markings into the environment.

Semi-volatile organic compounds (SVOCs) can also be released from road markings in the form of Polycyclic Aromatic Hydrocarbons (PAHs). These contaminants are from the additives present in road markings. While older formulations released a significant amount, more modern road markings have reduced the amount of PAHs that are released- though some PAHs content is still released when the marking is weathered or abraded. They are persistent in our environment due to their hydrophobicity- meaning they are primarily found bound to sediment particles within stormwater runoff. These particles consist of fine-grained particles (PM64), such as clays and silts which are harder to remove from stormwater runoff but essential to remove as they tend to contain the highest traces of contaminants.

3.4 Glass Microbeads

Glass microbeads (reflectors) are sized between 0.1mm and 1mm (specific sizing is dependent on specific site characteristics). They themselves are persistent, non-biodegradable particles that can be mobilised and released into the environment when a road marking is weathered, eroded or cracked. They can act as a direct carrier for paint residues, which may contain contaminant traces of heavy metals or VOCs.

Within the glass microbeads, traces of metal concentrations, such as arsenic (As), lead or antimony (Sb) may exist. This can be due to the manufacturing process of glass microbeads commonly using recycled glass and therefore the chemical composition of each batch varies slightly. Heavy metals can be added in the manufacturing process to improve the microbeads' clarity or refractive index. For example, arsenic can be used as a high temperature oxidant to remove impurities and help produce microbeads that are more transparent and brighter.

4.0 How do Road Markings Contribute to Stormwater Runoff Pollution?

Once a road marking is laid it is exposed to the abrasion caused by vehicle tyres. This wear and tear slowly release micro-particles and contaminants that are found within the formulations of the road marking. More prominent wear and tear of road markings occur at roundabouts or junctions as vehicles physically drive over the marking more often.

Road markings are also weathered down by changes in temperatures, which causes the road marking to crack, chip, peel or separate from the road surfaces. Rainfall can also slowly erode the road markings and make it adhere less to the road surface. UV exposure can break down pigments within the road marking, causing them to fade and lose reflectivity more quickly than expected.

The released particles can be transported by water or wind (depending on their size and particle size distribution found within the stormwater runoff). Stormwater runoff is likely to entrain these particles within its flow as TSS (Total Suspended Solids) and transport them via drainage systems from roads into receiving water such as river, lakes or the ocean. The contaminants can stay in suspension in aquatic habitats or settle within soils and sediments, this creating contaminated soils, sediments and water that organisms must adapt to in order to survive.

5.0 Effects on Human and Environmental Health

5.1 Microplastics

Microplastic pollution has been a significant environmental pollutant for years with increasing concern in recent decades. Their release into the environment can harm aquatic habitats, aquatic life and soil organisms. The harm to these small organisms' growth, development and reproduction can create damaging effects to the entire food web that feeds from them. These effects can make their way up to top predators and even humans. Microplastics have been found in all the earth's spheres:

- Lithosphere- soil and sediments
- Atmosphere- indoor and outdoor air
- Hydrosphere- oceans, lakes, rivers and other water courses and runoff like stormwater and wastewater
- Biosphere- microorganisms, animals, vegetation and humans

These spheres constantly interact with one another, exchanging matter, which in this case includes microplastics that become mobile from the abrasion of road markings. The distribution of microplastic is already enormous, with well documented concern about global emissions. The research into road marking pollution has identified another source of microplastic release into the environment. It must be addressed and mitigated accordingly for our future sustainability and resilience.

5.2 Heavy Metal Elements

Heavy metals can pose several serious health risks to humans and affect the proper functioning of living organisms. effects can be seen if humans drink contaminated water or eat food from contaminated soils or waters. Heavy metals can also accumulate within environments- these being terrestrial soils or aquatic sediments- affecting the functional processes of animals and poses risks of survival for vulnerable species.

The release of Pb, Cr, Ti, Zn, Ba, As, Sb and any other heavy metals from road markings is a concern for ecological health and animal wellbeing. Like microplastics, the effects can make their way up to higher feeding predators affecting their behaviour and growth. Chromium is a known carcinogen, and many heavy metals have toxic, carcinogenic properties and can disturb DNA, enzyme, nuclei and mitochondria within animals and humans. generally, heavy metals have been known to increase cancer risk, cardiovascular disease and infertility, and also damage vital organs such as lungs, kidney, liver and the brain. With more knowledge on the effects from exposure to heavy metals, more restrictions are put in place on their use in industries- these restrictions differ worldwide.

5.3 Volatile Organic Compounds

VOCs pose severe health risks to humans and animals when dissolved or associated with sediment in stormwater runoff. The toxicity can begin with accumulation in bottom-dwelling organisms. These organisms are the link between primary producers and higher-level predators in the food chain, meaning concentrations of VOCs within bottom-dwelling organisms may bioaccumulate in higher feeding organisms- which may even be humans.

In aquatic environments, algae naturally release allelochemicals (specialised biochemicals) to inhibit the growth of neighbouring species and promote their own growth/ survival. These allelopathic interactions allows species to compete for light, nutrients and space without physical crowding. This interaction occurs in many different water bodies such as lakes, rivers, reservoirs, or marine environments (coastal waters). Algae often release VOCs to act as allelopathic chemicals. Anthropogenic VOC pollution (such that from road markings) that enters receiving waters through stormwater runoff and drainage networks interferes with the natural allelopathic dynamics that exist. This disruption reduces oxygen concentrations in the water, leading to potential die-offs of certain species (vegetation or animal species) in the ecosystem. This threatens the survival of organisms that live there with overall degraded water quality levels and reduced biodiversity.

Acute effects that VOCs can have on humans include: being an irritant to eyes, nose and throat, causing headaches, nausea, dizziness and difficulty when breathing. Chronic effects in humans can cause damage to the liver, kidney and central nervous system. VOC content has also been linked to developmental and reproductive effects and possibly cancer- there is a classification of around 20 compounds which are cancerous.

Semi-volatile organic compounds such as PAHs pose similar acute effects to humans as VOCs do. However, PAHs may also weaken human immune systems or cause heart/ cardiovascular disease. They are also lipophilic, therefore can pass through biological cell membranes with ease and bioaccumulate in

aquatic organisms once they have entered receiving water bodies- affecting the survival of aquatic species.

5.4 Glass microbeads

Glass microbeads themselves act as a persistent physical pollutant rather than a toxic pollutant. They can contribute to changes in the topography at the bottom of water bodies and block habitats. This affects the survival of aquatic organisms and requires them to adapt to the new, potentially, toxic environment. Toxic effects come from the chemicals that may be attached to the microbead outer surface (e.g. heavy metals).

6.0 Mitigation Strategies

Road marking pollution is a lesser-known pollution source that is beginning to gain increasing scientific attention but is currently still under researched in practice. In studies, road marking pollution is often categorised under general ‘road pollution’, alongside tyre wear particles, brake wear particles and road surface particles. This is despite all four of these sources having significantly differing abrasion rates and contributing different concentrations of varying contaminants into our environment. The best-case scenario to mitigate this pollution source would be to reduce/ stop the release of particles from road markings altogether thus reducing the contamination of our aquatic and terrestrial environments. However, this is not a feasible option as alternative chemicals that produce similar outputs and functions of road markings have yet to be identified.

Sustainable Drainage Systems (SuDS) are designed to treat and remove contaminants from oncoming stormwater runoff before they enter receiving natural waters. A treatment train is an effective way to target the removal of different contaminants that can exist in one flow. Different techniques include sedimentation, filtration and adsorption systems. It is best practice to target coarser materials first in a treatment train to reduce the likelihood of blockages of further treatment steps occurring.

The hydrodynamic vortex separators- 3P Technik’s HydroShark and filters like the 3P HydroSystem provide a two-step sedimentation-filtration treatment train. The 3P HydroShark removes a large proportion of settleable solids before the partially treated stormwater runoff is directed through the 3P HydroSystem filter system. This is where finer particles are retained through the four treatment processes of sedimentation, filtration, adsorption and ion exchange.

A significant proportion of contaminants stated above can be removed from stormwater runoff after being directed through this 3P Technik treatment train.

The implementation of stormwater treatment devices (SuDS techniques) may be the best way to afford the continued use of materials and chemicals within current road markings, until safer alternatives that can provide similar functions are identified.

7.0 Conclusion

Road marking pollution is a less obvious but significant contributor of harmful chemicals to aquatic environments. The maintenance, age, traffic load and environmental factors all affect the amount of

contaminants that could be released from road markings into stormwater runoff. If not removed, the pollutant loaded TSS within stormwater runoff can cause detrimental effects to animals, vegetation, humans and the water quality of receiving water bodies. The best option to mitigate this contamination issue, is to reduce possible contamination within the road marking formulations themselves, and to otherwise reduce the distribution of contaminants once released into the environment.

At present reducing the distribution of contaminants is the most realistic option as safer alternative products with the same performative functions and outputs are hard to come by. Stormwater treatment is best achieved by implementing treatment trains as a form of Sustainable Drainage Systems (SuDS) to target the removal of specific contaminants and particle sizes.

8.0 Further Information

3P Technik's technical team can provide project-specific advice and support. Please contact us to discuss your requirements. Tel: +44 (0)1239 623506, Email: sales@3ptechnik.co.uk.

This article is published on the 3P Technik website: <https://3ptechnik.co.uk/road-runoff-pollution-how-road-surfaces-and-road-markings-release-microplastics-and-toxic-contaminants/>

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