ROAD MARKINGS AND MICROPLASTICS

Supporting Information for the ERF Position on the Situation

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The ERF Position in brief

Road markings, a highly specialised variety of industrial coatings that are inalienable safety features at almost all roads, contribute only negligibly to the pollution caused by secondary microplastics (*synthetic polymer microparticles*). Because there is no reliable method for measurement of these emissions, reporting on their potential quantities would be burdened with enormous error and as such futile. The easiest and most efficient method to minimise the contribution of road markings to microplastic pollution is through measures that would promote their appropriate upkeep and consistent maintenance of high performance standards.

Preamble

The proposed legislation aiming at limiting the emissions of secondary microplastics would also comprise road markings, which would be treated as other industrial coatings. Unfortunately, the specificity of road markings was disregarded and their inclusion was not subjected to appropriate review and comments from the perspective of academic and industrial professionals working with them. The life cycle of road markings, with **clearly distinguished *functional* and *physical* service life**, was not considered, which lead to the plethora of errors. Because of this distinction and their features, road markings should be considered separately.

The absence of solid reliable scientific knowledge related to the emissions of secondary microplastics from road markings must be emphasised, so reporting the quantities would be completely unreliable – based on assumptions and not on facts. As such, it would only cause unnecessary bureaucratic effort and be generally counterproductive. Recent scientific research (abrasion estimates, validated by sparse findings even in the roadway dusts and runoffs) shows that the leakage of plastics from road markings to the environment is very low. From a practical perspective that would benefit the entire society, promotion of road marking materials providing prolonged service life together with their appropriate upkeep are seen as highly efficient and relatively inexpensive measure to practically eliminate the risk of microplastic emissions from this potential source.

Literature reports

There are several reports (note that they were not peer-reviewed), in which it was estimated that microplastics originating from road markings could constitute approximately 7%[1,2] of all of the microplastics emissions, with the reported values ranging from 0.7%[3,4] to 19%[5]. In the majority of these reports it was incorrectly assumed that the paint applied would almost equal the paint lost[6,7] – it is inherently inaccurate because the loss of functional properties is not tantamount to the physical loss of road markings from the roadway. Upon the loss of functional properties, road markings are renewed, which causes stacking of their layers; in scientific literature one can find images of samples collected in the field with more than 10 layers[8].

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To add to the information chaos and inconsistency, some authors claim high data reliability[9], while others, working on the same data set, indicate high uncertainty[7].

One must observe that microplastic particles positively assigned as originating from road markings were reported only by six research groups: in five instances, they originated from thermoplastic road markings that were neglected[10] or subjected to special local abrasion conditions[11,12,13,14,15] and in one case it was a seldom-used material for a special application[16]. Simultaneously, in a plethora of roadside dust and wastewater collection campaigns no fragments of road markings were identified[17,18,19,20,21,22,23,24,25,26,27,28,29,30]. This obvious incongruity between large quantities of estimated emissions and sparse identification can be explained by considering the uniqueness of road markings.

It must be underlined that besides the presence of embedded glass beads and holes from them[10,11,14,15], there is no known reliable analytical method to distinguish pieces of road markings and those originating from other pollution sources. Development of such method should be amongst the key research activities. Important additional caution must be given: the sole presence of glass beads in a roadside dust or runoff[31,32,33] is not sufficient abrasion indicator because other drop-on glass beads could be still protecting the paint layer. In addition, the same type of glass beads are commonly used as fillers in plastic composites[34], as blasting media for abrasive cleaning of surfaces[35], and as filtration media[36].

Unique features of road markings

There are two key features related to road markings that must be comprehended and which make them clearly different than other coatings: their dual layer character and the renewal procedures that create the aforementioned distinction between *functional* and *physical* service life. These aspects cause any assumptions analogous to other coatings inadequate.

Firstly, road markings are distinct from other industrial coatings because they always comprise two vastly dissimilar layers: a coating (paint) layer and a glass beads layer[37,38]. The bottom coating layer contains polymeric binder and upon abrasion could contribute to microplastic pollution indeed. However, the top glass beads layer (drop-on glass beads) is protecting the underlaying coating layer from abrasion and simultaneously provides the critical **functional parameter**: retroreflectivity[39].

> Retroreflectivity is measured through coefficient of retroreflected luminance (R_L) and expressed in the units of millicandela per square metre per lux (mcd/m²/lx). Other functional parameters of road markings, such as daytime visibility (measured through luminance coefficient under diffuse illumination (Qd), also expressed in mcd/m²/lx) and skid resistance (measured with British Pendulum Skid Resistance Tester that provides unitless Pendulum Test Values) are known by industry professionals to fail only after R_L failure occurs and thus play marginal role in determination of the functional service life.

Secondly, upon the loss of retroreflectivity, road markings are not replaced, but renewed – hence, stacking of layers occurs[8]. Consequently, the process of life cycle of road markings can be divided into *functional life time* (when their R_L and other parameters exceed the minimum regulatory requirements) and *physical life time* (when road markings no longer meet the

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requirements and can undergo abrasion and thus physical removal from the roadway). The life cycle steps of road markings are shown in Figure 1 below; they can be described as follows:

(1) New materials (layers of the coating and the drop-on glass beads) are applied, typically R_L>300 mcd/m²/lx is obtained.

(2) The road markings undergo wear and tear. At this point it is critical to understand that tyres are rolling on the glass beads and cannot touch the coating layer.

> It is physically impossible that a tyre would touch the coating layer because it is protected with a layer of glass beads (the drop-on glass beads, typically 0.1−1.4 mm in diameter, are embedded to approximately 50% and cover roughly 30% of the surface). These dimensions should be compared with a typical tyre contact patch size (approximately 100×150 mm, i.e. about 200× larger than an average glass bead) and a single tyre tread (approximately 10×20 mm, i.e. >10× larger than an average glass bead); hence, tyre rubber cannot fit between the glass beads to touch the underlaying coating layer and abrade it.

(3) Upon wear and tear, the surface of glass beads is physically damaged (scratching[40]) and some glass beads are extracted from the coating layer. Loss of R_L occurs until it drops to the critical minimum value demanded by local regulations, usually 100 mcd/m²/lx. Typically, more than 4 million tyre rollovers are required to reach such low R_L; homologation processes assure that this absolute minimum is reached.

> At that point, *functional service life of road marking ends* and they are ***renewed***. Renewal means covering the existing road markings with another layer of coating and glass beads – the process cycles to point (1). Until this point, the emissions of microplastics from road markings are marginal because there was no contact between the tyres and the coating. The thickness of the coating layer does not decrease.
>
> Upon stacking of layers of road markings, their total thickness increases. When it reaches the locally prescribed maximum (typically about 6 mm), the accumulated layers are mechanically removed. The removal process is to be done without the release of dust and the waste is collected and disposed appropriately. Hence, despite numerous layers, the entire procedure can be considered as a closed system, with only minimum leakage.

(4) There are situations when excessive forces (particularly those caused by turning vehicles, but also in areas exposed to other extraordinary conditions like frequent snow ploughing or the use of studded tyres) result in accelerated local failure of R_L through glass beads extraction from the coating layer before renewal takes place. At such locations, R_L drops further. Based on professional experience from field observations, R_L>50 mcd/m²/lx (in white road markings) means that glass beads are still present on their surface (because a coating without glass beads delivers R_L<30 mcd/m²/lx). At that point, the protection of the polymer-bearing coating layer provided by glass beads layer is only marginal. Only under such rare circumstances, abrasion can commence and emissions of microplastics do occur until the end of physical service life is reached.

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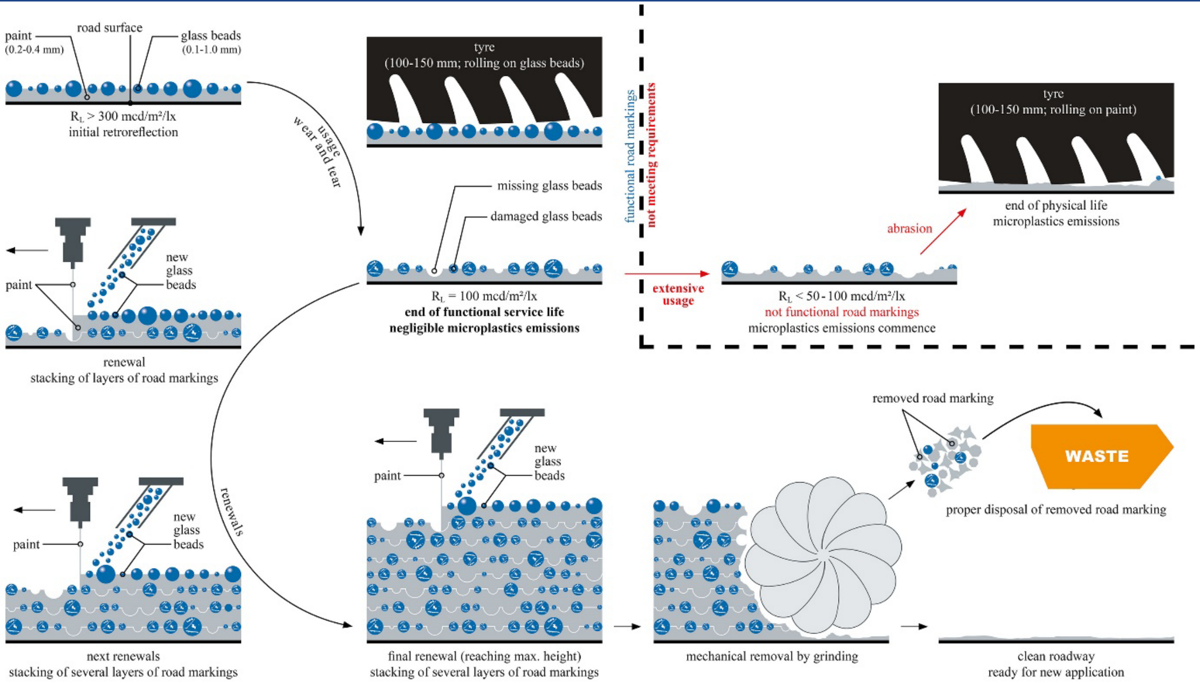

Figure 1. Life cycle of road markings.

A visual confirmation that the loss of the coating layer material (i.e. potential to contribute to secondary microplastic pollution) is insignificant due to the protection given by the glass beads layer is shown in Figure 2; it is a picture of a test panel that was subjected to 12 million tyre rollovers in a test done according to the procedure demanded for German approval for use on roads[41] (even if the homologation for this type of paint would demand meeting the functional service life requirements for only 4 million rollovers) − glass beads are still present and protect the paint.

Figure 2. Test panel after 12 million tyre rollovers. Drop-on glass beads protect the underlaying paint from abrasion.

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The proof for stacking of many layers of road marking materials are images of cross-sections of samples of road markings collected in the field: Figure 3 (thermoplastic road markings, thick layer application, each layer 1.5 ±1.0 mm thick), Figure 4 (paint, thin layer applications, each layer 0.2 ±0.1 mm thick), and Figure 5 (cold plastic, a thick layer road marking, renewed with two thin layers of paint).

Figure 3. Three layers of thermoplastic road markings. Visible damage from studded tyres that penetrated the surface. Glass beads visible at the top of each layer indicate that the older layer was not abraded meaningfully.

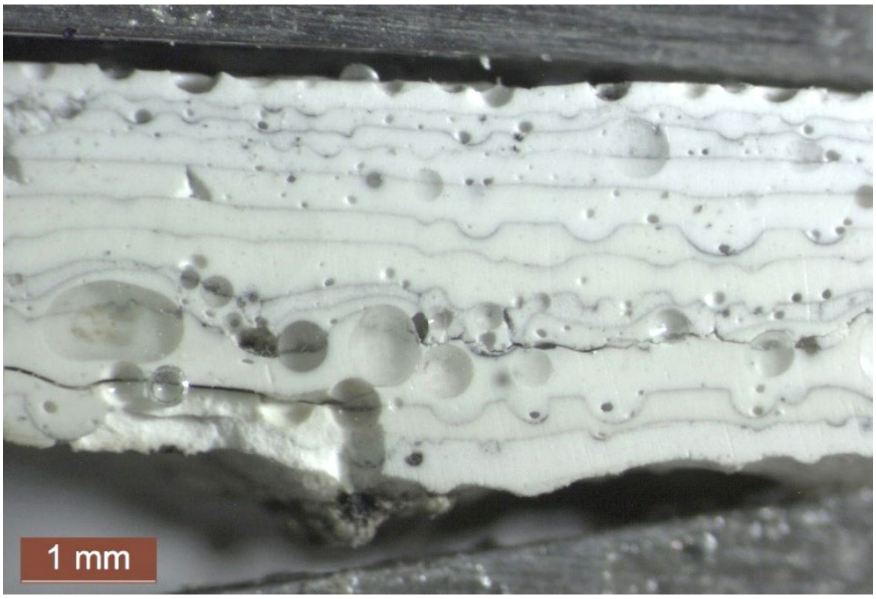

Figure 4. Twelve layers of paint. Glass beads visible at the top of each layer indicate that the older layer was not abraded.

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Figure 5. Cold plastic road marking (thick layer) renewed twice with paint (thin layer). Glass beads visible at the top of each layer indicate that the older layer was not abraded.

Based on a field assessment of abrasion of road markings through evaluation of their luminance (with the assumption that road markings surface is white and the underlaying asphalt roadway surface is black), loss of road markings at pedestrian crossings' 'zebra' stripes (the worst-case scenario because the stripes are most extensively used marked area; they comprise less than 10% of all applied markings) was estimated at only 0.2−4.8%, which would correspond to the secondary microplastics emissions of 0.1−4.3 g/year/person. These results, from an assessment performed in the field, ought to be compared with theoretical claims that up to 100% of road markings would be lost and emissions estimates range 19.3−121.1 g/year/person; hence, the values provided by numerous assessments were grossly overestimated[8]. Similarly low losses of road markings, below 5%, are reported in statements from DSGS[42] and SER. Indeed, <5% of all organic road wear particles within the range 2−125 µm from road dust collected in Sweden were attributed to road markings[15].

Other considerations

It is necessary to separately assess the situation in Nordic countries, where studded tyres are commonly used in winter, regardless of the presence or absence of snow. The studs do cause excessive damage because they can reach the coating layer while glass beads are still present. This is strictly a *local issue*; the only reasonable solution that can be proposed would be imposing a ban on the studs[43,44,45]. Hence, the estimated road marking loss measured at a pedestrian crossing in Sweden was 22.1% (i.e. 56.3 g/year/person), within the range of previous approximation[46]. However, one must add two caveats: (1) vast majority of road markings applied in the Nordic countries are thermoplastic masses, which are designed for slow wear to continuously deliver R_L – it is considered a safety feature, and (2) the possibility of using *non-polymeric binders* in these thermoplastic road markings[8]. While these two considerations are very important, further deliberation would depart from the main topic.

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Any discussions related to the materials choice are futile because *all road markings undergo the same life cycle process* and because the only important parameter controlling the sustainability of the road markings is their durability (i.e. functional service life)[39,47,48]. From practical perspective, it is noteworthy that high-end road markings that furnish prolonged functional service life were calculated to be also the most economical choice[49]. It cannot be forgotten that the main purpose for the installation and maintenance of road markings is proper channelling and organising traffic flows, which results in meaningfully increasing road safety[50,51]. The utility of road markings for advanced driver assistance systems and for the emerging technology of autonomous vehicles must also be noted[52,53,54,55]. There are no other known equally efficient and inexpensive solutions for traffic safety[56].

Summary

In conclusion, road markings are unique amongst coatings because the polymer-bearing coating layer is protected by a layer of glass beads; as long as glass beads are present, the emissions of synthetic polymer microparticles do not occur beyond a negligible quantity. Because the loss or damage of glass beads signal the end of *functional service life* and the necessity of renewal, road markings seldom are subjected to abrasion to reach the *physical end-of-life* when they could become a meaningful source of pollution. In samples collected in the field, multiple layers were seen, which confirmed that renewals occurred before abrasion took place.

Based on field assessment, it was demonstrated that the contribution of road markings to all secondary microplastic pollution was not more than 4.3 g/year/person, even at the most utilised areas. This value must be compared with the reported confirmed contributions from other road sources: the wear of tyres that add 230−4700 g/year/person[57] and the yet unquantified emissions from polymer-modified bitumen where losses of approximately 0.5 g of plastic particles per m² of asphalt surface were reported[58].

Recommendation

Due to unique features, road markings should have been exempted from the proposed legislation because they would not readily fit within the statute. Whereas they can undergo abrasion and contribute to secondary microplastic pollution, it can occur only on materials that lost their functional properties; hence, their leakage to the environment is marginal. In the light of the absence of a reliable test method and the negligible contribution, the proposed reporting would only generate administrative burden and expenses without measurable benefits.

Instead of pointless reporting requirements, ***the proposal from the perspective of road marking industry is to impose high standards on the upkeep of road marking based on R_L. Simultaneously, this would be the easiest, the most efficient, and the least expensive method to minimise the emissions of secondary microplastics from road markings to practically nil.*** To achieve such goal, materials with the longest functional service life should be promoted to minimise carbon footprint[39] and road markings ought to be renewed while they still provide R_L>150 mcd/m²/lx, as was postulated by the ERF[59]. Maintaining such retroreflection level

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would fulfil visual needs of drivers[60,61], should lead to increased road safety[51,62], and also would improve the performance of advanced driver assistance systems[52,54,55,63].

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