Evaluation of Leaching Potential of 6PPD-Q from Rubber Modified Asphalt

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Rubber-Modified Asphalt (RMA): Market Size

- In 2019, US produced 420,000,000 million tons of asphalt mix
- If each ton of asphalt mix is modified with 10 lbs of rubber per ton (standard norm), then:
  - ***We need 2.1 million tons of rubber to modify all asphalt mixture produced in US***
- A typical scrap tire weighing 27 lbs. contains 70% recoverable rubber, i.e. 18.9 lbs. of recoverable rubber
- In 2019, US produced 263.4 million scrap tires ➔ 4,978,260,000 lbs. of rubber or 2,489,130 tons
  - ***We can produce 2.5 million tons of ground tire rubber from the scrap tires generated in US***
- ***Bottomline: We can use up all scrap tires produced in the US in asphalt mixtures***

Why modify asphalt with rubber?

1. Performance
2. Sustainability
3. Economics

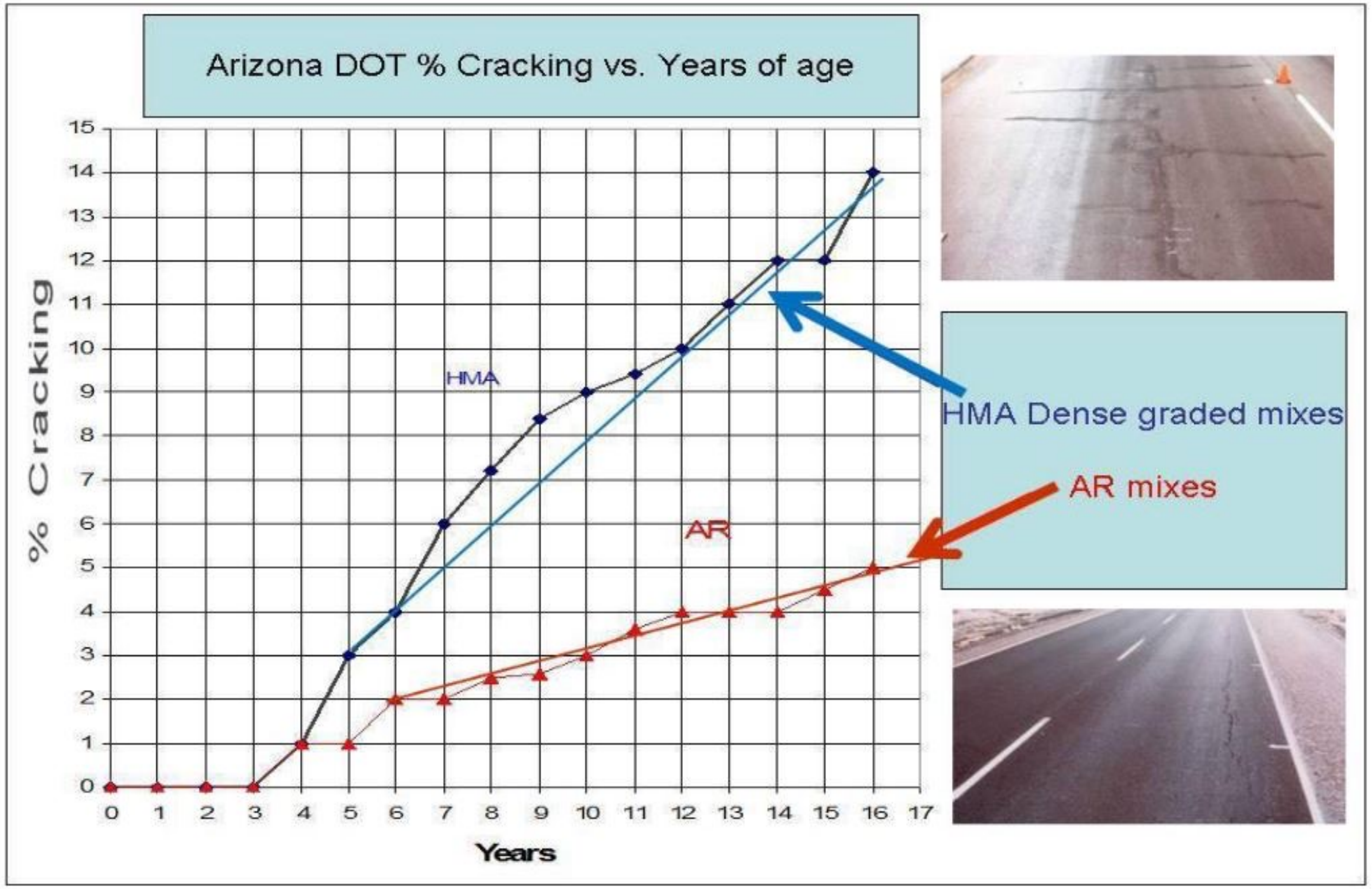
Why modify asphalt with rubber: Performance

1 Performance

2 Sustainability

3 Economics

RMA is able to provide performance and functional benefits including **longer service life**, **lower noise**, and **better ride** quality, and **increased skid resistance**



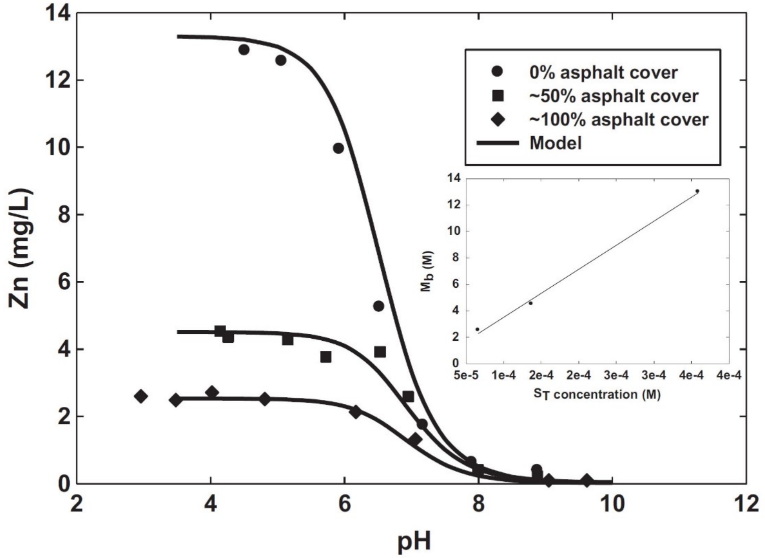
Why modify asphalt with rubber: Sustainability

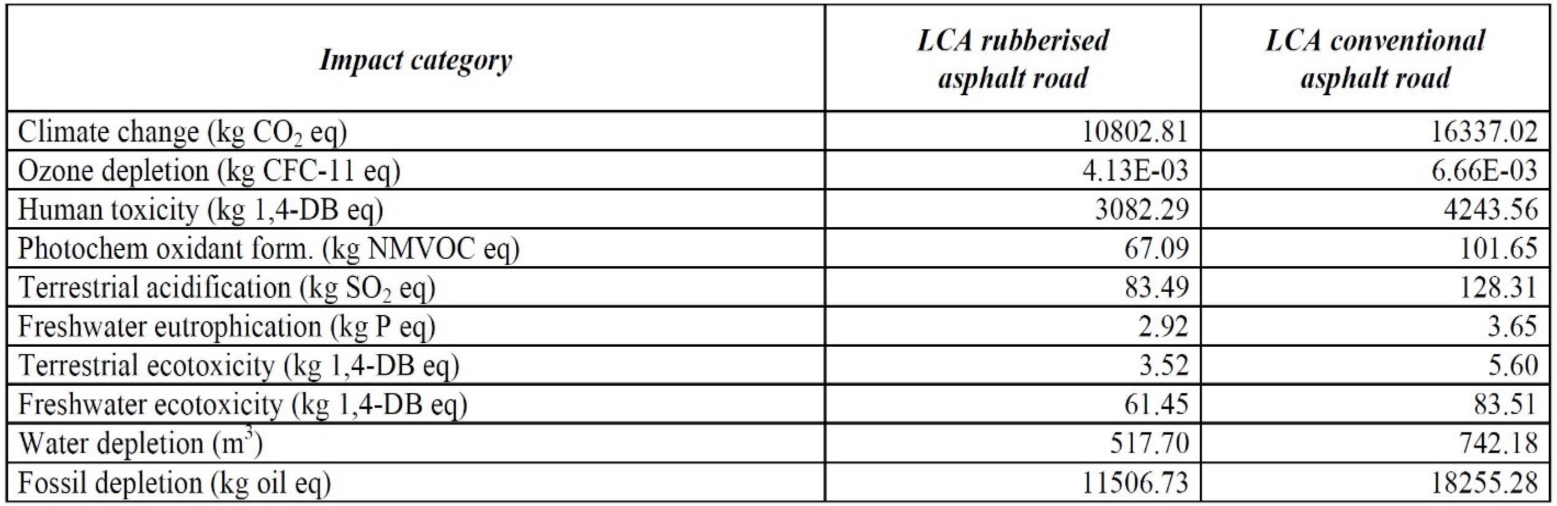
1 Performance

2 Sustainability

3 Economics

- LCA studies with proper assumptions show **reductions in environmental impact when using RMA**, ~30-40% reduction
- Entombment of rubber particles in asphalt results in **significant decrease in leaching** ~85% reduction





Impact category	*LCA rubberised asphalt road*	*LCA conventional asphalt road*
Climate change (kg CO_2 eq)	10802.81	16337.02
Ozone depletion (kg CFC-11 eq)	4.13E-03	6.66E-03
Human toxicity (kg 1,4-DB eq)	3082.29	4243.56
Photochem oxidant form. (kg NMVOC eq)	67.09	101.65
Terrestrial acidification (kg SO_2 eq)	83.49	128.31
Freshwater eutrophication (kg P eq)	2.92	3.65
Terrestrial ecotoxicity (kg 1,4-DB eq)	3.52	5.60
Freshwater ecotoxicity (kg 1,4-DB eq)	61.45	83.51
Water depletion (m^3)	517.70	742.18
Fossil depletion (kg oil eq)	11506.73	18255.28

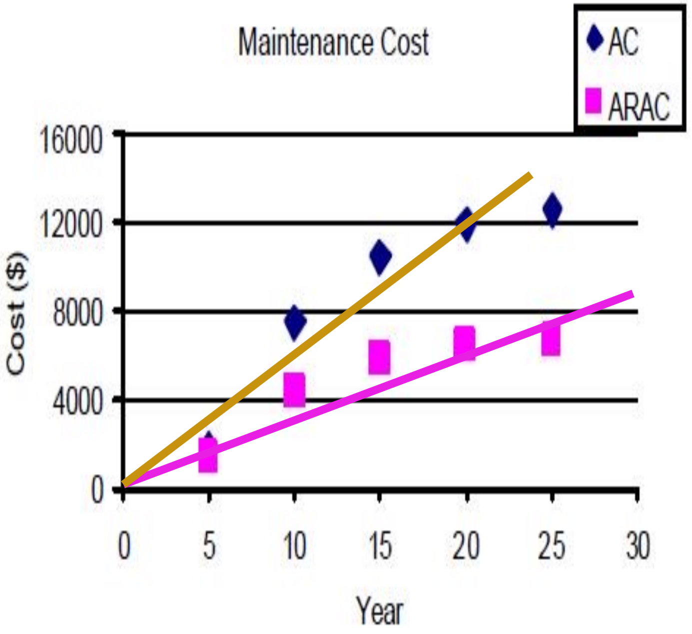
Why modify asphalt with rubber: Economics

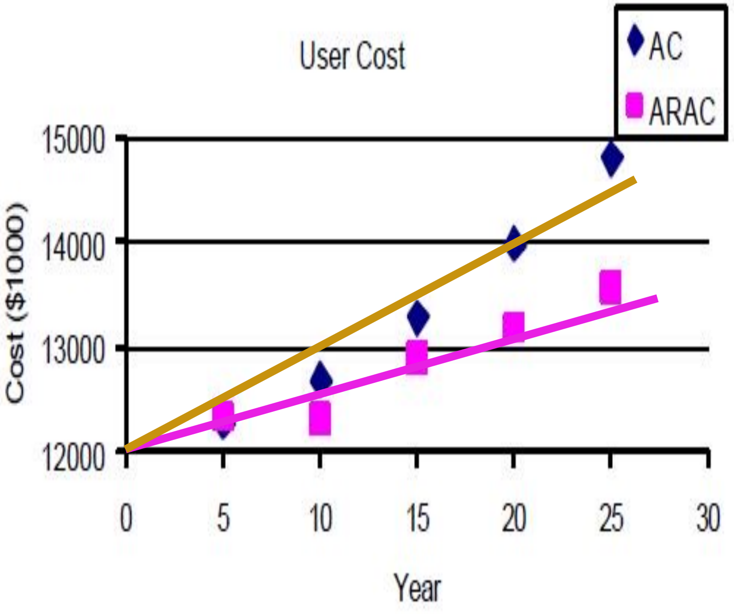
1 Performance

2 Sustainabilit

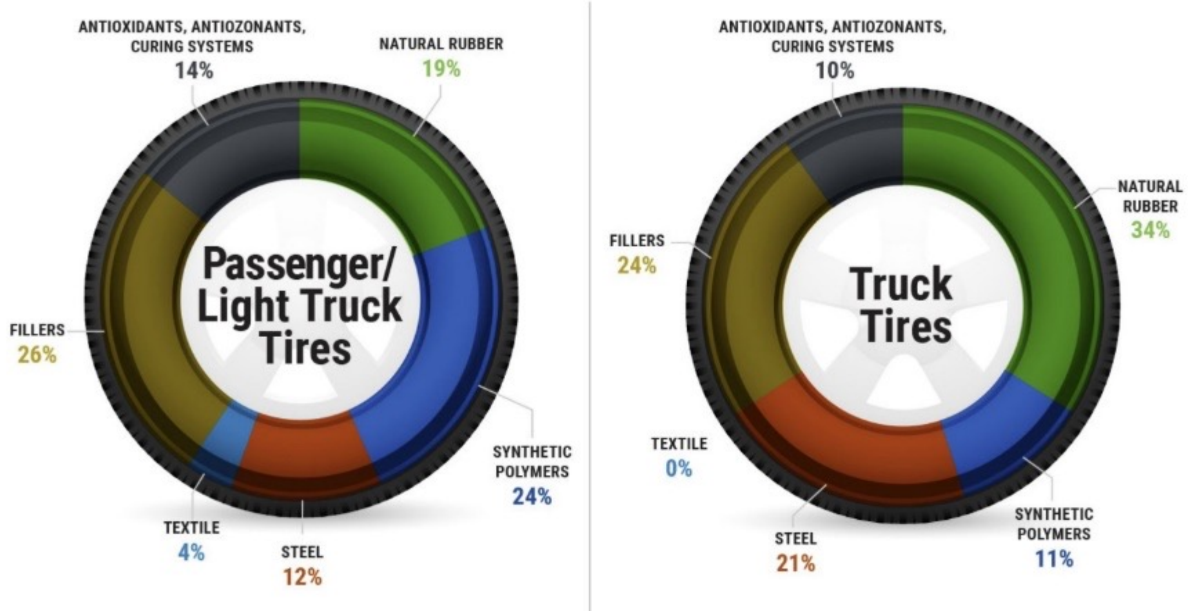
3 **Economics**

- **Heavy traffic applications**: Modern RMA mixtures are **less expensive than polymer-modified asphalt mixtures** and provide **comparable performance**
- **Light & medium traffic applications:** Could make thinner lifts (50% thinner with same performance) and last longer ➔ **more cost effective**



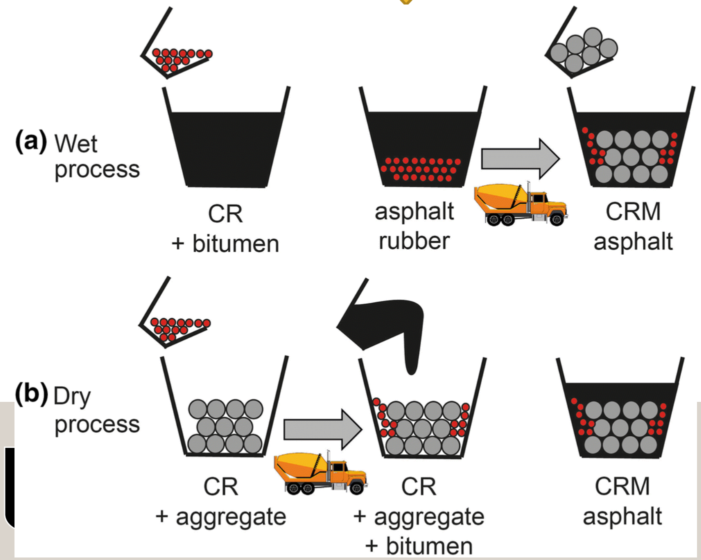


Modification Methods



End of Life
Tire Recycling

Ground Tire
Rubber (GTR)



Conventional Paving
Equipment/Process

RMA Pavement on
Illinois Tollway

Problem Statement

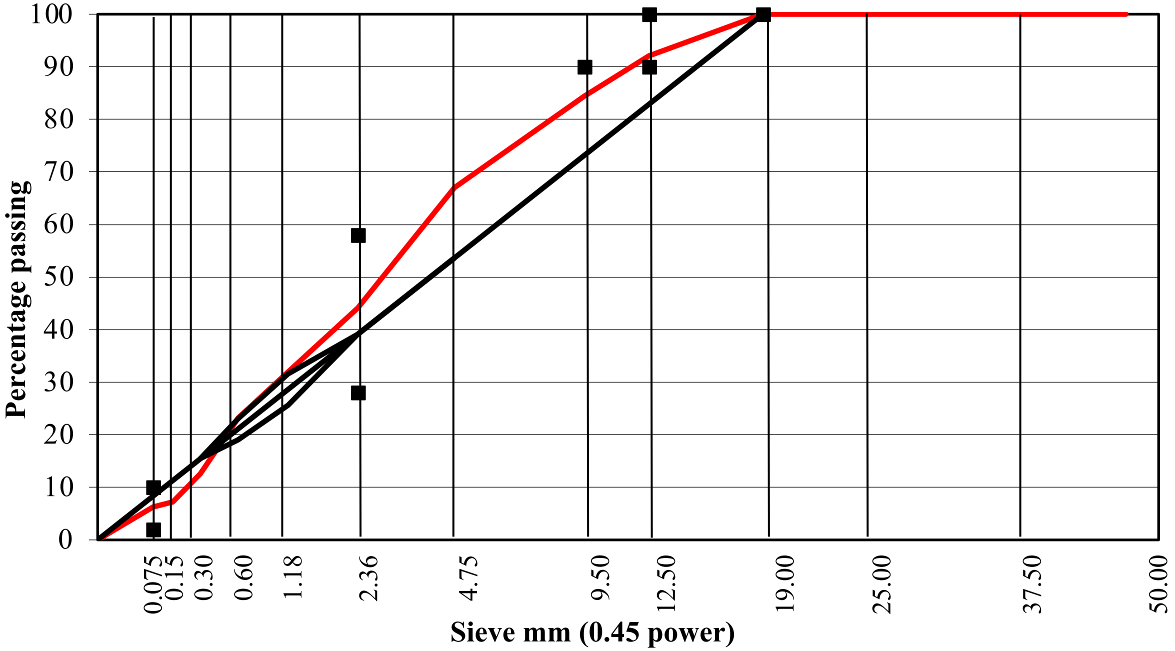
With an increase in the adoption of Rubber-Modified Asphalt (RMA) in pavement construction and in light of new environmental questions raised based on recent reports of 6PPD-Q toxicity to certain aquatic species, there is a need to evaluate the leaching characteristics of RMA.

Research Approach

- Produce asphalt mixtures modified with and without rubber
    - Include virgin polymer modified mixture in the testing matrix for comparison
- Establish controlled protocols to capture sample leachates from existing lab-scale tests
- Cracking Test : Samples were subjected to an indirect cracking test at room temperature and water was passed through these cracked specimens. The collected water was analyzed for 6PPD and 6PPD-Q. This represented the leachate traveling through pavement cracks and air voids
- Rutting (Hamburg) Test : Samples were subjected to steel wheel abrasion while submerged under water at elevated temperature till 20 mm rut was observed. The water was collected and analyzed for chemicals

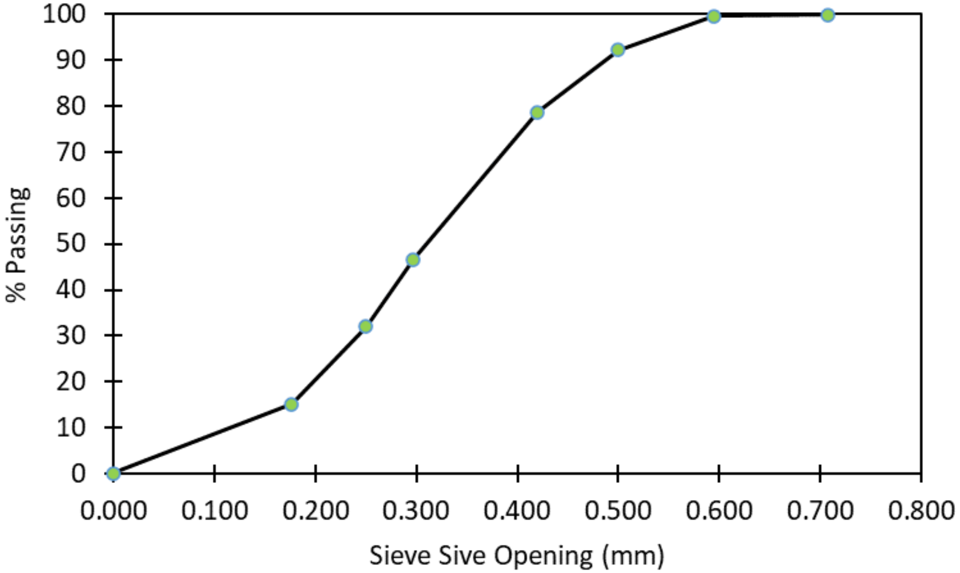
Mix Details

- 12.5 NMAS, dense graded mix
- PG64-22 base binder, 4.8-5.0% AC



GTR Details

- 98% passing 30 mesh; ambient grind
- Dry GTR had <1% by weight chemical coating (workability enhancer)



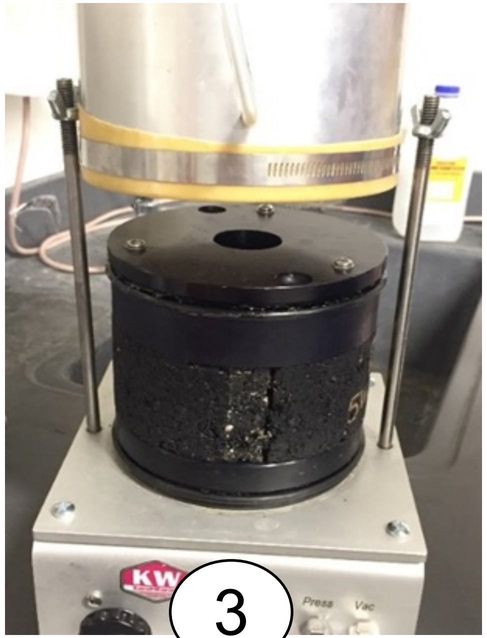
Cracking Test Details and Protocols

1

Specimen is put through an indirect tensile test to produce a crack

2

Cracked specimen is loaded into a falling head permeability device



3

Specimen enclosed in rubber walled chamber and water is flushed through it (500 ml DI water)

Rutting/Abrasion Test Details and Protocols

1

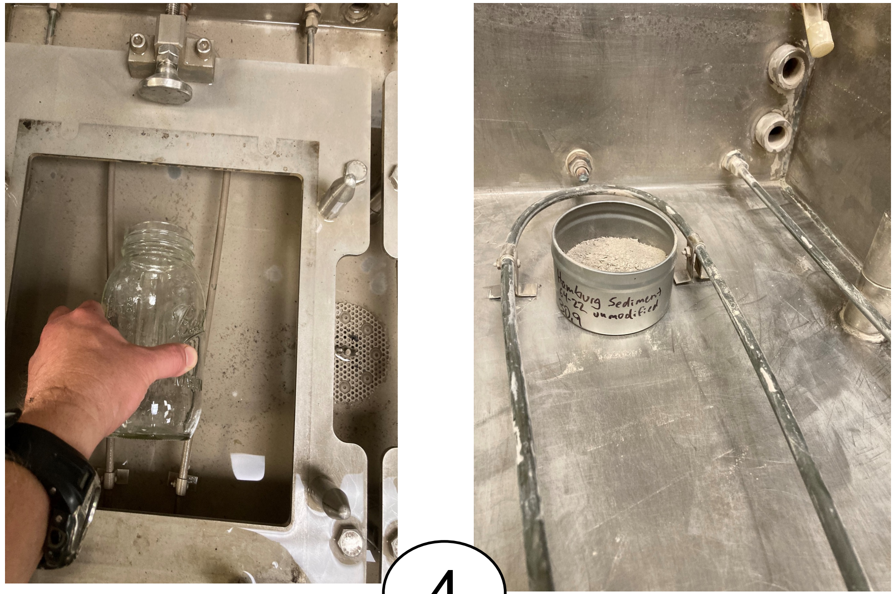
Hamburg machine is thoroughly cleaned, dried to avoid cross-contamination

2

Steel wheels run till 20 mm rut or for 40,000 passes under submerged conditions (50°C)

3

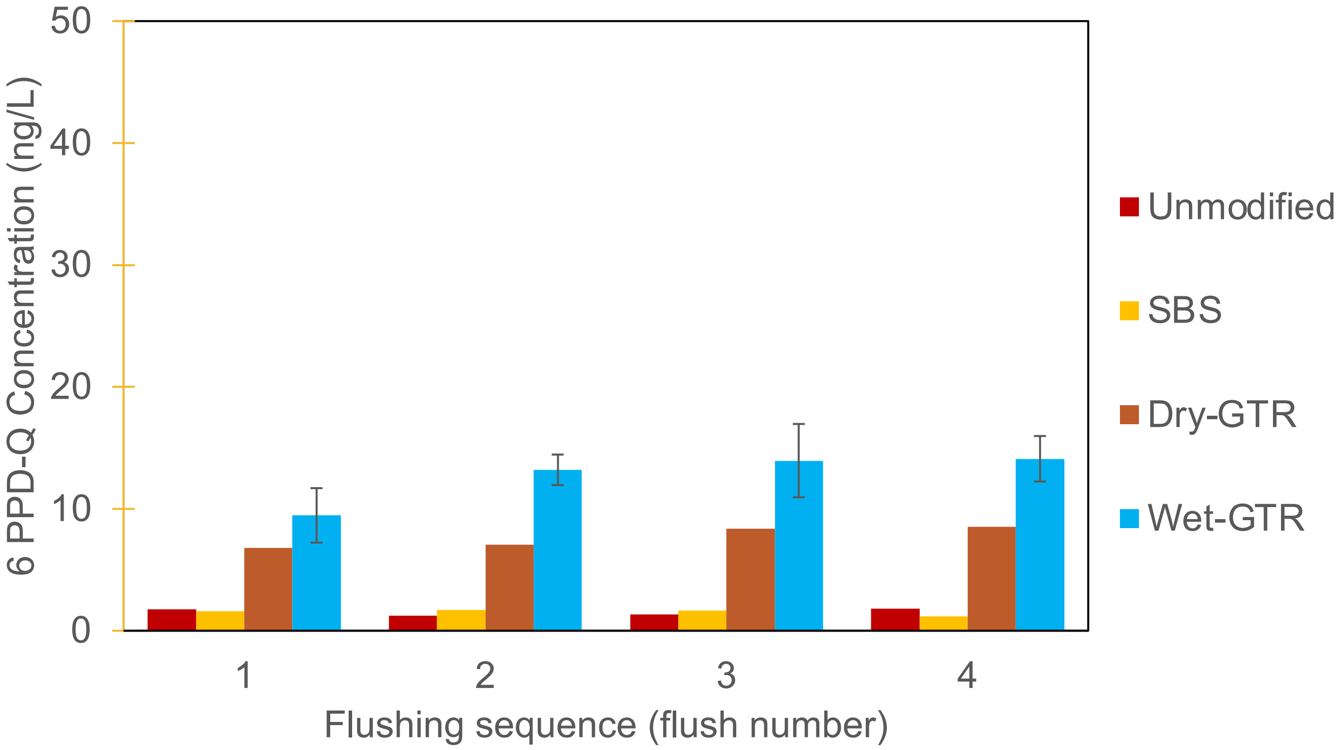
Specimen shown at the end of 20 mm or 40,000 passes



4

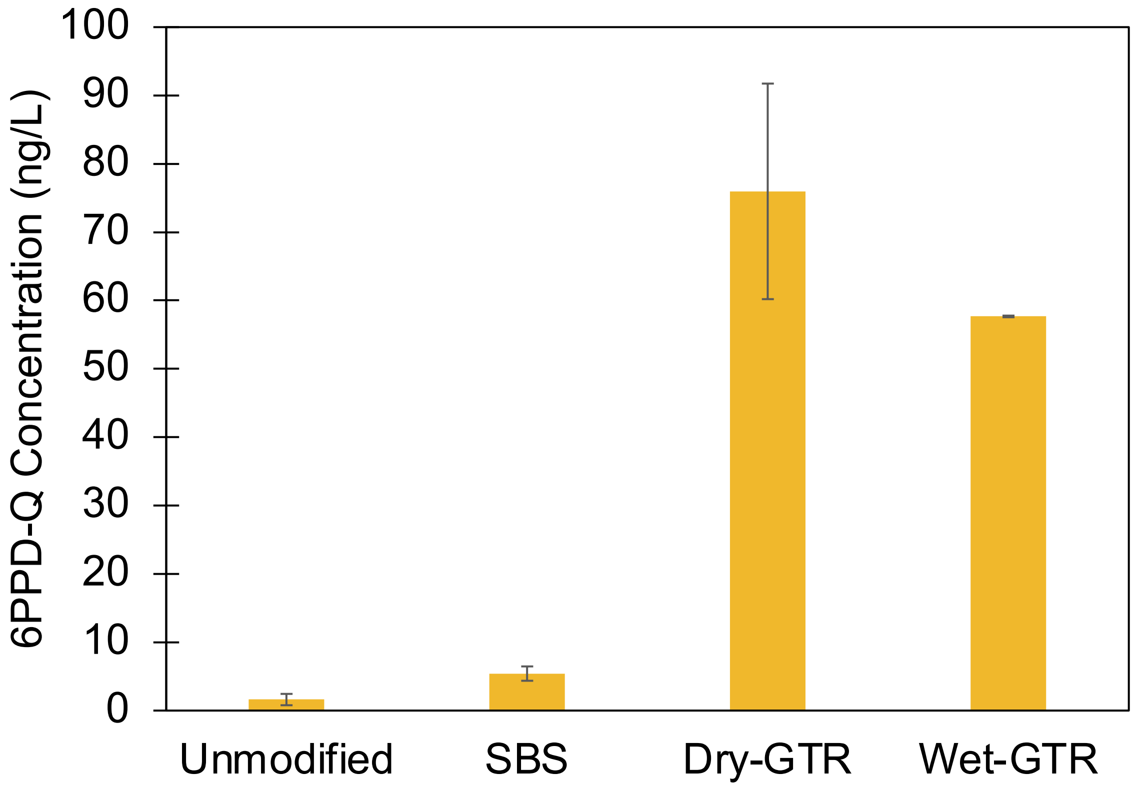
Sediments are allowed to settle down; water is collected at various levels before being drained; Sediments are collected and analyzed; Machine is cleaned, dried, and loaded with next round of replicates

Results and Discussion



- Results obtained for four flushes for all specimens
- Multiple wet-GTR specimens were evaluated to understand specimen-related sensitivity
- Some background contamination from rubber housing in the unmodified and SBS modified mixtures
- Overall, the concentrations were low; wet GTR reported highest concentrations

Results and Discussion



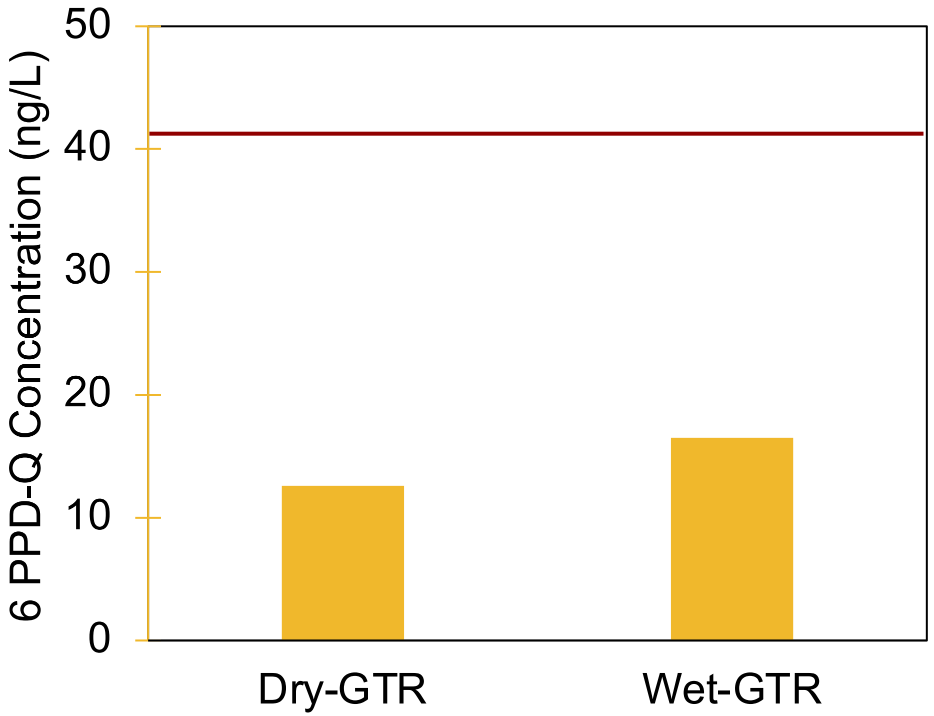
- This represents an extreme, conservative upper limit of pavement degradation (steel wheel abrasion)
- Some background contamination observed in unmodified mixture
- Dry GTR reported higher concentrations and variability as well
- Lab to field scaling analysis with this data is critical and is presented next

Lab to Field Scaling: Approach and Assumptions

- The Hamburg laboratory leachate concentrations were scaled according to the relative proportions of water in the lab vs. the field (over a 15-year pavement performance period before replacement)
- Based on volume of water in the Hamburg tank, and the annual rainfall received in Columbia, MO, a dilution factor was computed to translate the lab data to an upper limit estimate of field leaching
- The permeability leachate rate was directly used to estimate the upper-limit of field leachate caused by water running over the surface and through air voids
- Pavement layer thickness was assumed to have a minimal effect since most leaching would likely occur from the top layer. In addition, the thickness of the test specimens (62 mm) is in range of a typical asphalt overlay

Lab to Field Scaling: Results

- Following the outlined approach, a dilution factor of 6.52 was computed to scale the Hamburg data to field observation
- For dry-GTR, a conservative upper limit estimate of 6PPD-Q concentration at the edge of the pavement was found to be 12.6 ng/L, and for wet-GTR, it was found to be 16.5 ng/L
- Based on previously established LC50 threshold of 41 ng/L, this represents about 30.7% and 40.2% of the LC50 value for dry and wet process RMA respectively



Additional Context

- The Hamburg wheel tracking test is expected to produce more abrasion and damage to an asphalt mixture as compared to actual pavement loading, due to the use of a steel wheel, which is used for the purpose of accelerating the rate of rutting in the laboratory
- The sorbancy of pavement infrastructure (including the asphalt itself, plus base materials, shoulder, and embankment surfaces) will tend to reduce the concentration of leachates in stormwater discharges from the roadway corridor
- 6PPD-Q leachate rates from a given mass of tire rubber will both decrease with time in terms of leaching concentration at the source location and will decrease according to its aqueous stability, thus lowering the relative impact of its downstream effects
- Roads represent <1% of surface area of the US, even when excluding Alaska (FHWA). Thus, although impervious surfaces such as roads generate 3 to 5 times the runoff rate compared to forested areas, stormwater runoff from roadway surfaces represents only a fraction of the total stormwater released to streams and rivers.

Summary and Conclusions

- With roads representing such a huge market for use of end-of-life tires, it is important to understand their long-term environmental effects
- In this study, lab test protocols were established to obtain leachates from RMA mixtures for 6PPD-Q estimation
- Protocols included a permeability test wherein water was passed through a centrally cracked specimen and a torture test wherein steel wheels were run over submerged specimens at elevated temperatures
- Lab results were scaled to very conservative field observations

Summary and Conclusions

- 6PPD-Q levels from lab rutting tests were expectedly much higher than the cracking tests
- Upon scaling the results to field estimations, the 6PPD-Q concentrations were in the range of 30-40% of the established LC50 value
- Actual concentrations of 6PPD-Q in sensitive aquatic environments are expected to be lower for a number of factors including sorption, the gradual breakdown of 6PPD-Q in the environment, and dilution with other stormwater and groundwater sources
- Based on the analysis conducted in this study, RMA pavements are not expected to produce any concerning levels of 6PPD-Q in most watersheds, and will produce trace amounts in most locations

THANK YOU!!

QUESTIONS??

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