

# Tire-Derived Contaminants in San Francisco Bay

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# Tire tread wears off during use



# Most California stormwater flows directly to surface water without any treatment

Sewer



Storm  
Drain



# An estimated 5 trillion tire particles enter SF Bay annually from stormwater (125 $\mu\text{m}$ filter)



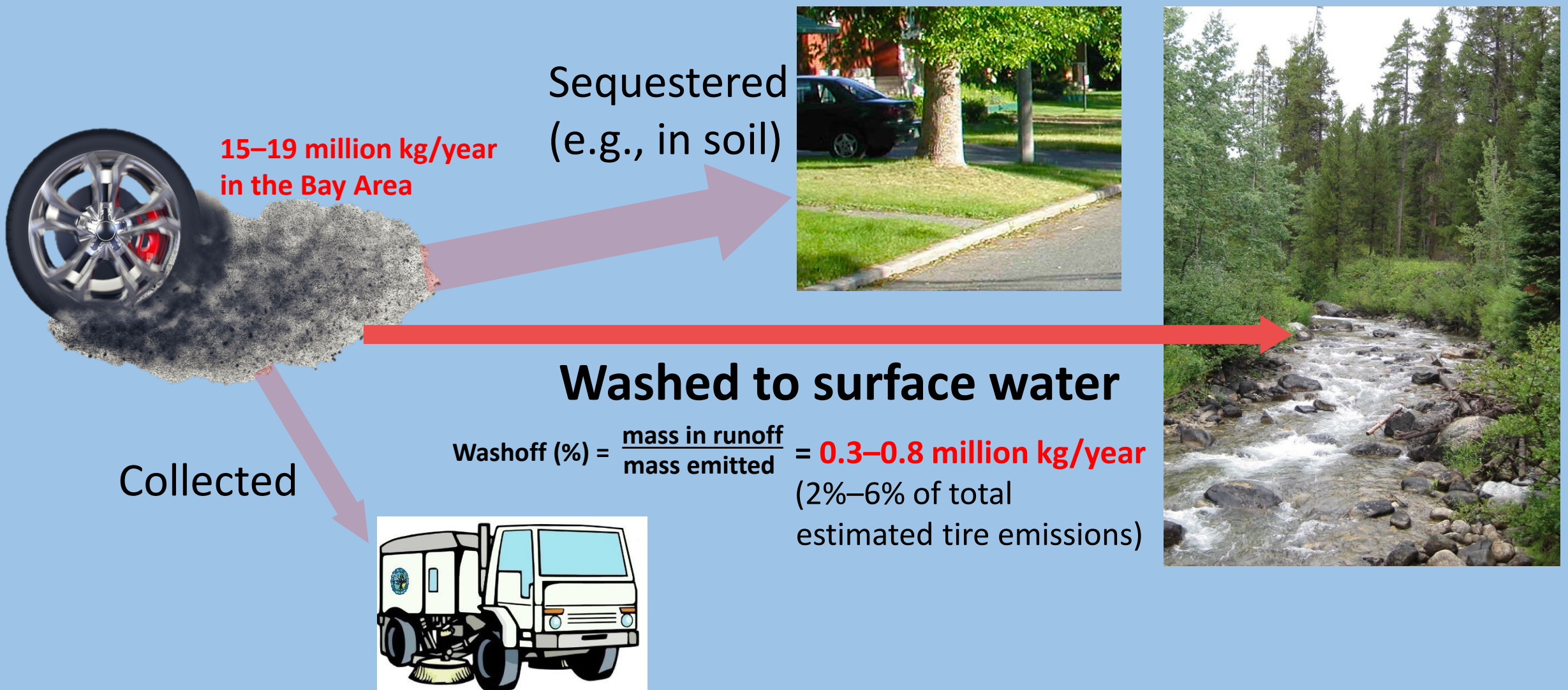


# Estimated Annual Tire Wear Emissions

<b>Location</b>	<b>Method 1</b> tire wear rates × vehicle distance traveled	<b>Method 2</b> tire sales × tread mass loss	Per Capita Estimated Emissions
SF Bay Area	15 million kg	19 million kg	1.9–2.4 kg
State of California	100 million kg	120 million kg	2.6–3.0 kg



# How much makes its way to surface waters?



# Chemical ingredients are an important part of tire particle transport and exposure



Tire  
Particles

Tires and the  
Chemicals  
they contain

Chemicals



# Growing body of tire toxicity evidence (selected papers)

Reference	Tested Species ( <b>observed affected in bold</b> )	Type of Tire Exposure			Authors consider exposure to be Environmentally Relevant Concentrations	Observed Affected Endpoints
		Microparticles	Nanoparticles	Leachate		
Ding et al. 2023	<b>Annelid worm (Enchytraeus crypticus)</b>	x		x	x	metabolics gut microbial community
Cunningham et al. 2022	<b>Zebrafish (Danio rerio)</b> <b>Daphnia magna</b>	x	x	x		behavior development mortality
Ding et al. 2022	<b>sediment microbial communities</b>	x		x	x	community structure/function
Schell et al. 2022	<b>Daphnia magna</b> Hyalella azteca Water louse (Asellus aquaticus) California blackworm (Lumbriculus variegatus)	x			x	reproduction mortality
Siddiqui et al. 2022	<b>Inland Silverside (Menidia beryllina)</b> <b>Mysid shrimp (Americamysis bahia)</b>	x	x	x	x	behavior growth
Tallec et al. 2022	<b>Pacific oyster (Crassostrea gigas)</b>			x		reproduction physiology
Selonen et al. 2021	Enchytraeid worm (Enchytraeus crypticus) <b>Springtail (Folsomia candida)</b> Woodlouse (Porcellio scaber)	x			x	reproduction mortality
Halle et al. 2021	<b>Hyalella azteca</b>	x		x		growth mortality



★ Tire chemicals of interest to CA Department of Toxic Substances Control (DTSC)

# Tire Chemicals of Interest

(not comprehensive)

Compound
6PPD/6PPD-quinone ★
Other PPDs
Benzothiazoles, DPG, HMMM ★
Chlorinated paraffins ★
Phthalates
Octyl phenol ethoxylates/ other alkylphenol ethoxylates ★
PAHs ★
Bisphenols
Zinc ★
Glycols & glycol ethers
Transformation products
Other chemicals (TBD) ★





MARCH 2022 • FINAL VERSION

Product - Chemical Profile for  
Motor Vehicle Tires Containing  
N-(1,3-Dimethylbutyl)-N'-phenyl-p-  
phenylenediamine (6PPD)



**Effective October 1, 2023:**  
California DTSC lists motor vehicle  
tires containing 6PPD as a Priority  
Product under the Safer Consumer  
Products Regulations

More info:  
[https://dtsc.ca.gov/scp/motor\\_ vehicle\\_tires\\_containing\\_6ppd/](https://dtsc.ca.gov/scp/motor_vehicle_tires_containing_6ppd/)



# Tire chemical leaching can cause toxicity



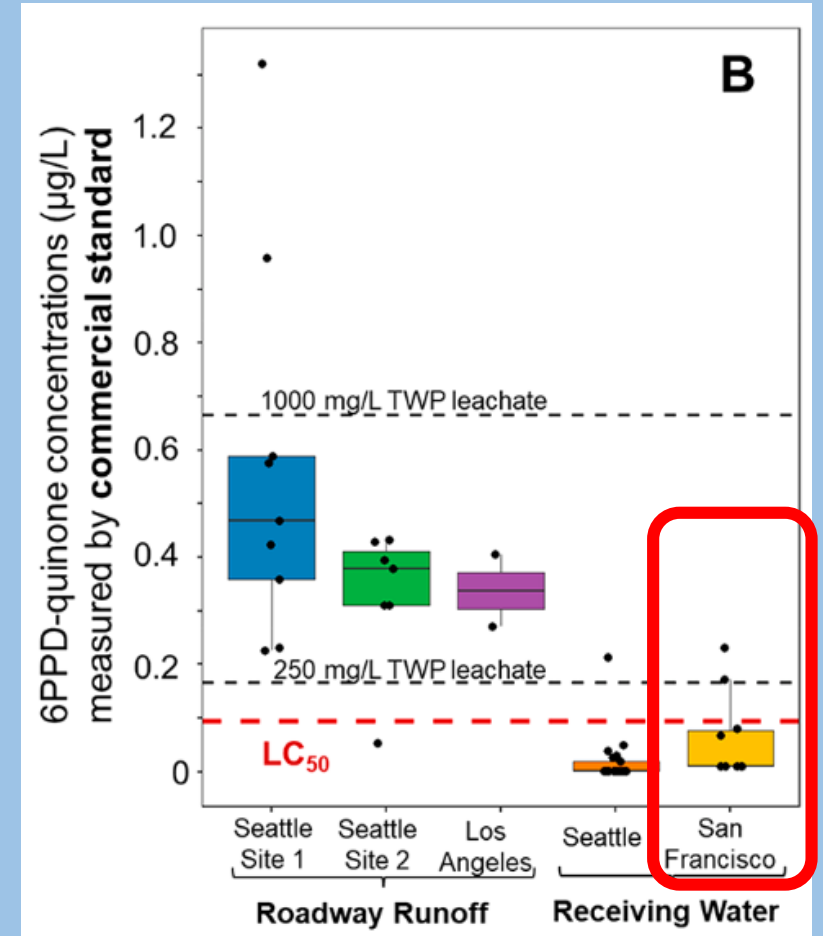
Tire ingredient  
6PPD

Ozone in air

6PPD-quinone  
in urban runoff



Coho salmon fish kills



SF Bay urban runoff-impacted  
peri-urban creeks (water year 2019)

# 6PPD-Quinone a concern not just for Coho

## Acute Toxicity of the Tire Rubber-Derived Chemical 6PPD-quinone to Four Fishes of Commercial, Cultural, and Ecological Importance

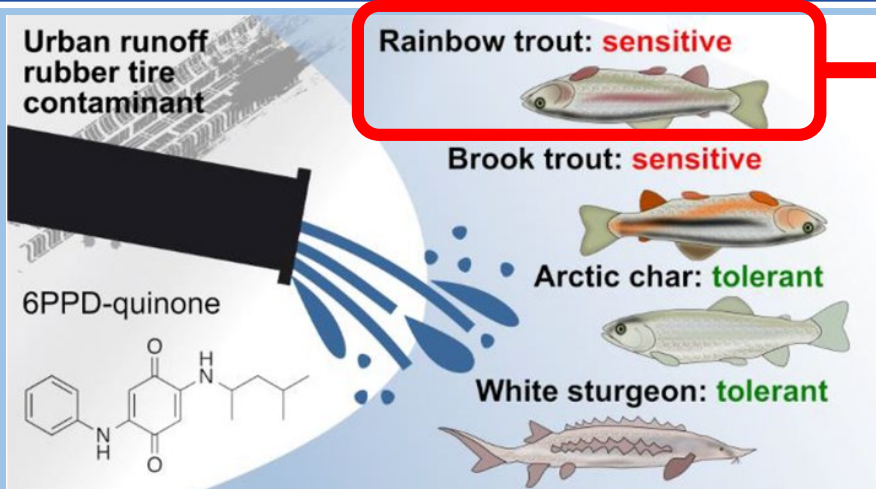
Markus Brinkmann, David Montgomery, Summer Selinger, Justin G. P. Miller, Eric Stock, Alper James Alcaraz, Jonathan K. Challis, Lynn Weber, David Janz, Markus Hecker,\* and Steve Wiseman



Cite This: <https://doi.org/10.1021/acs.estlett.2c00050>



Read Online



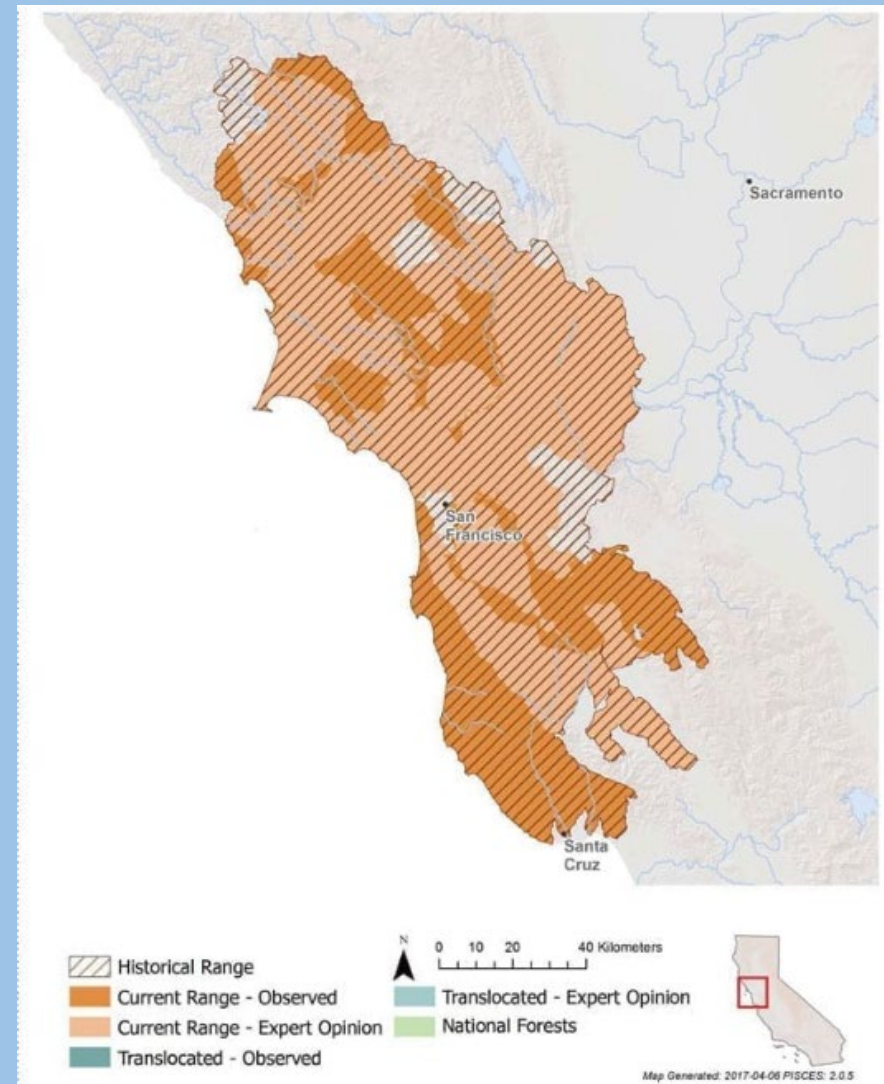
Rainbow trout = Steelhead, a threatened SF Bay species



# Steelhead



- 24 of 58 Bay watersheds support steelhead and/or resident rainbow trout
- Juveniles typically spend 1-2 years in freshwater before migrating to estuarine areas as smolts and then into the ocean to feed and mature
- Migration timing:
  - Juveniles migrate downstream to the Bay in late winter and spring.
  - Adults migrate from the ocean into freshwater streams to spawn Dec-Mar



★ Tire chemicals of interest to DTSC

# Tire Chemicals of Interest

(not comprehensive)

Compound	RMP monitoring
6PPD/6PPD-quinone ★	X
Other PPDs	
Benzothiazoles DPG, HMMM ★	X
Chlorinated paraffins ★	X
Phthalates	X
Octyl phenol ethoxylates/ other alkylphenol ethoxylates ★	X
PAHs ★	X
Bisphenols	X
Zinc ★	X
Glycols & glycol ethers	
Transformation products	(a few)
Other chemicals (TBD) ★	??

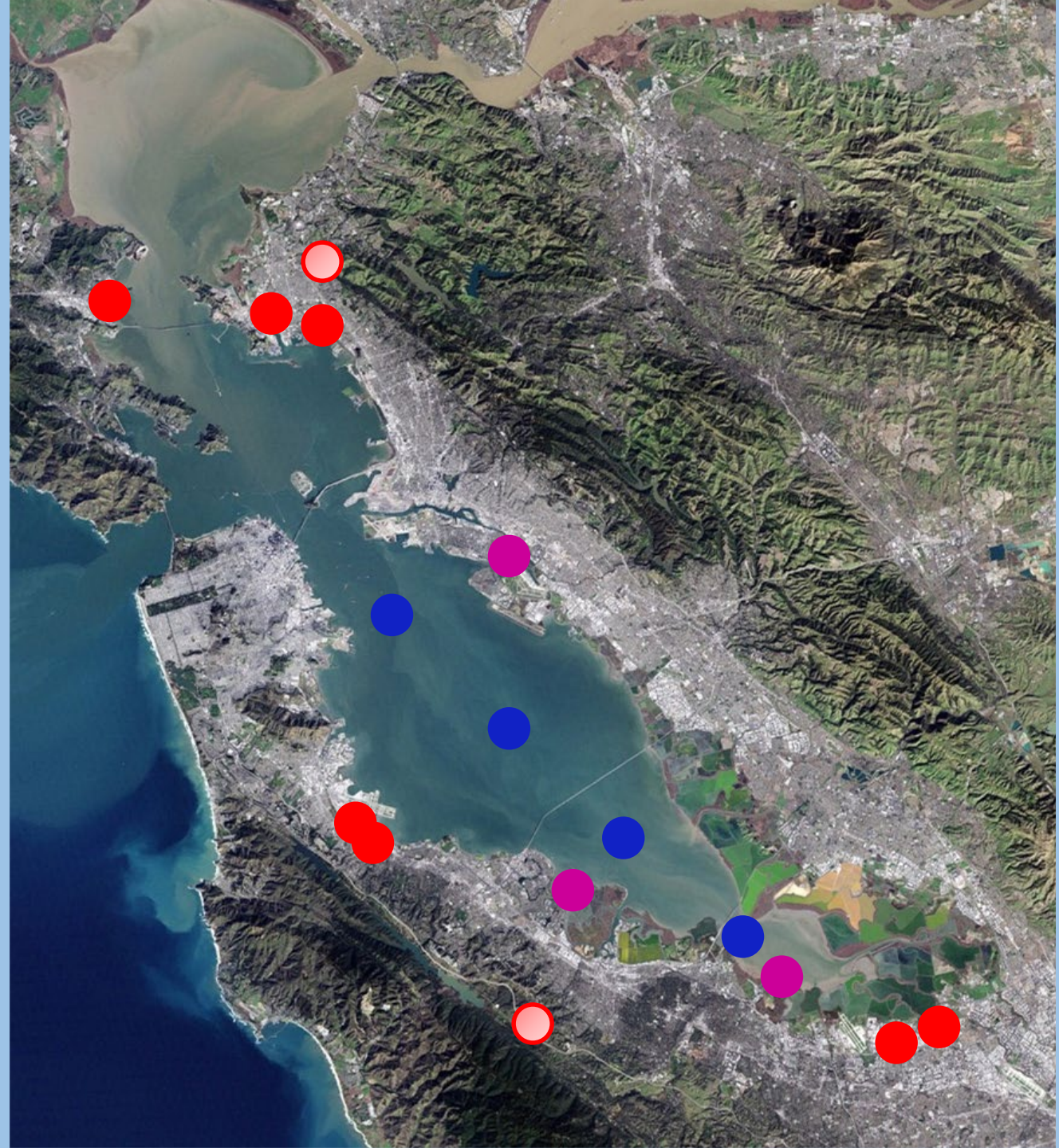
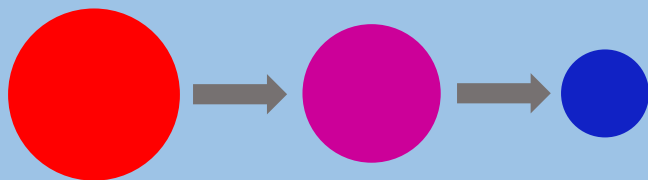


# Monitoring Design

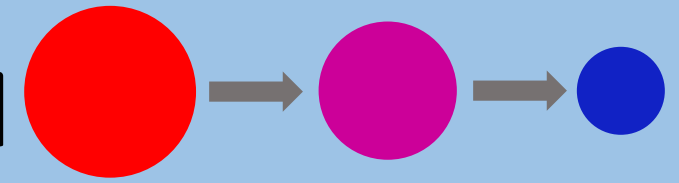
WY2022 - WY2024

- Urban Stormwater (7)
- Reference Stormwater (2)
- Near-field Bay (3)
- Open Bay (4)

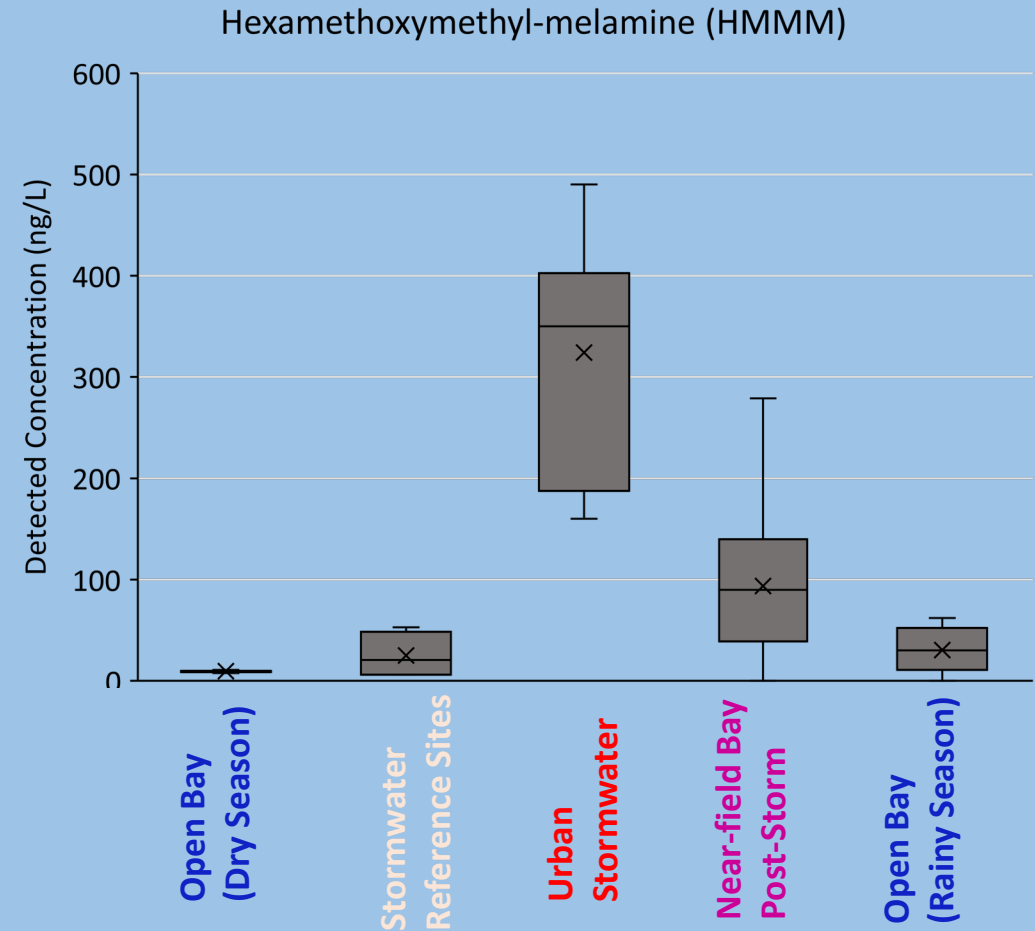
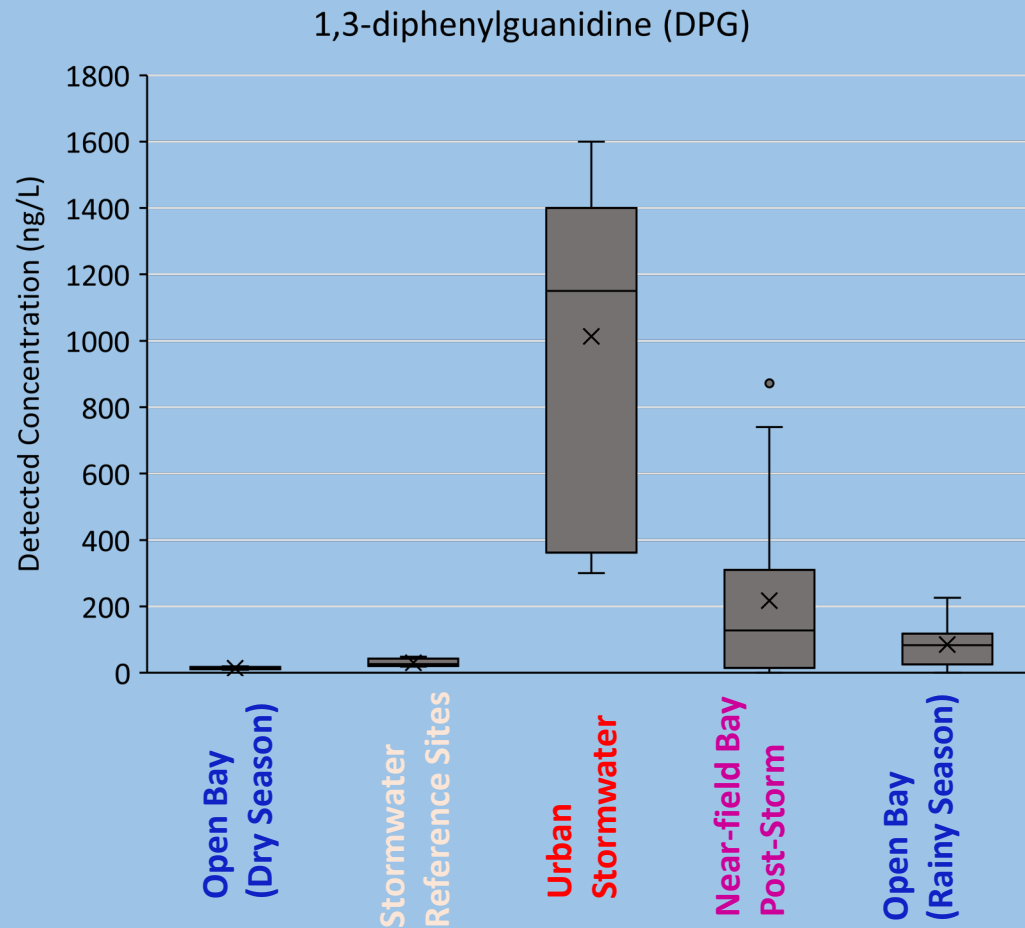
Hypothesis: concentrations decrease with dilution



# Selected Results: DPG and HMMM

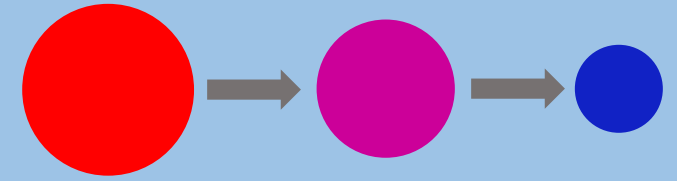


*Tire and roadway contaminants reach detectable concentrations in Bay water near stormwater discharge locations as well as in the center of the Bay, even with dilution from mixing.*

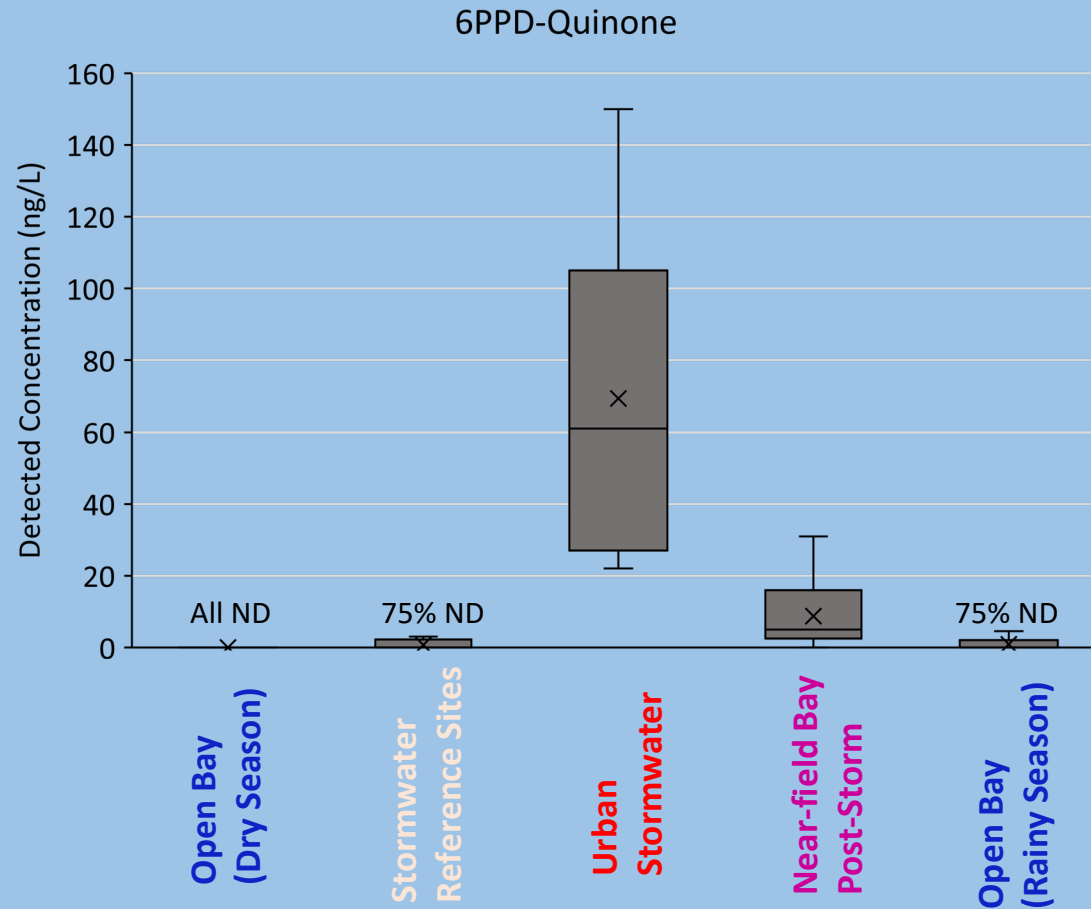




# Selected Results: 6PPD-Quinone



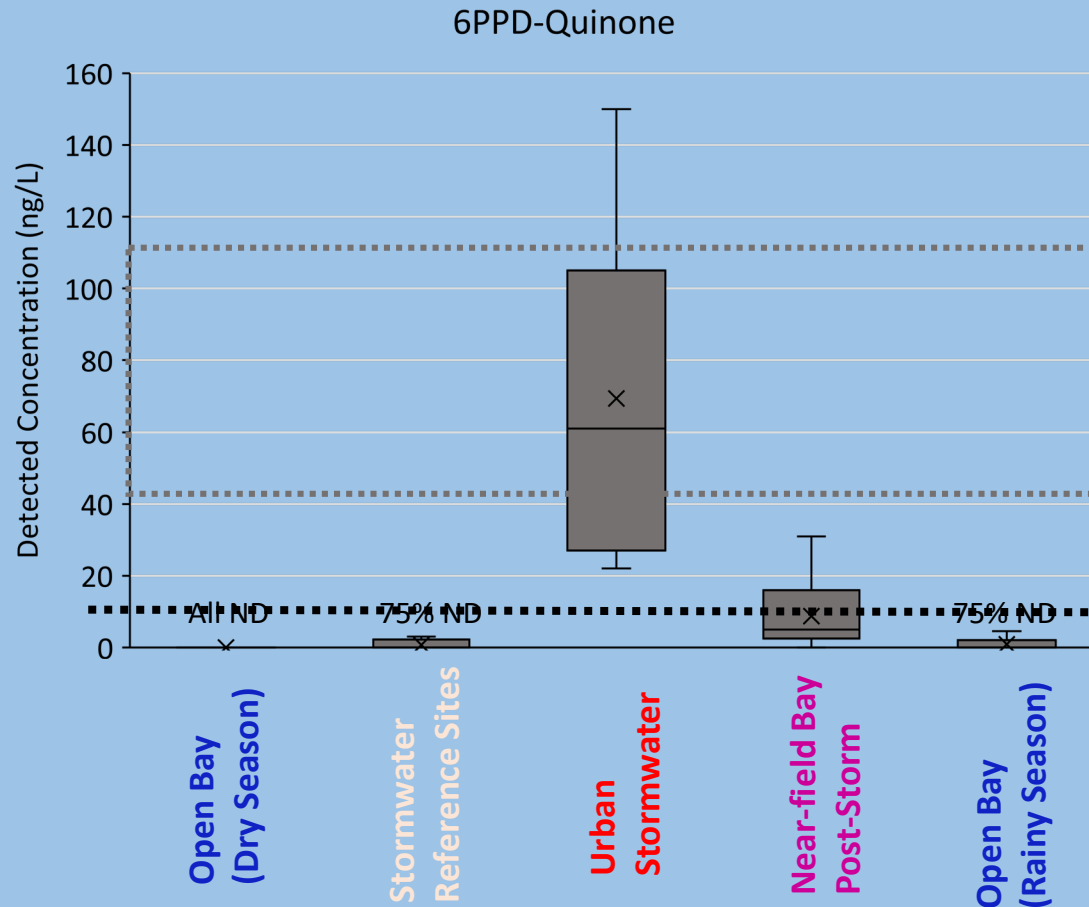
*6PPD-quinone reaches detectable concentrations in Bay water near stormwater discharge locations; concentrations below MDL in Open Bay (consistent with dilution modeling).*



# Selected Results: 6PPD-Quinone

*6PPD-quinone reaches concentrations that may cause toxicity (?)*

- Sublethal rainbow trout toxicity testing is in progress
- Salinity and co-exposed contaminants could also affect toxicity
- Toxicity to other organisms unknown



Steelhead /  
Rainbow Trout

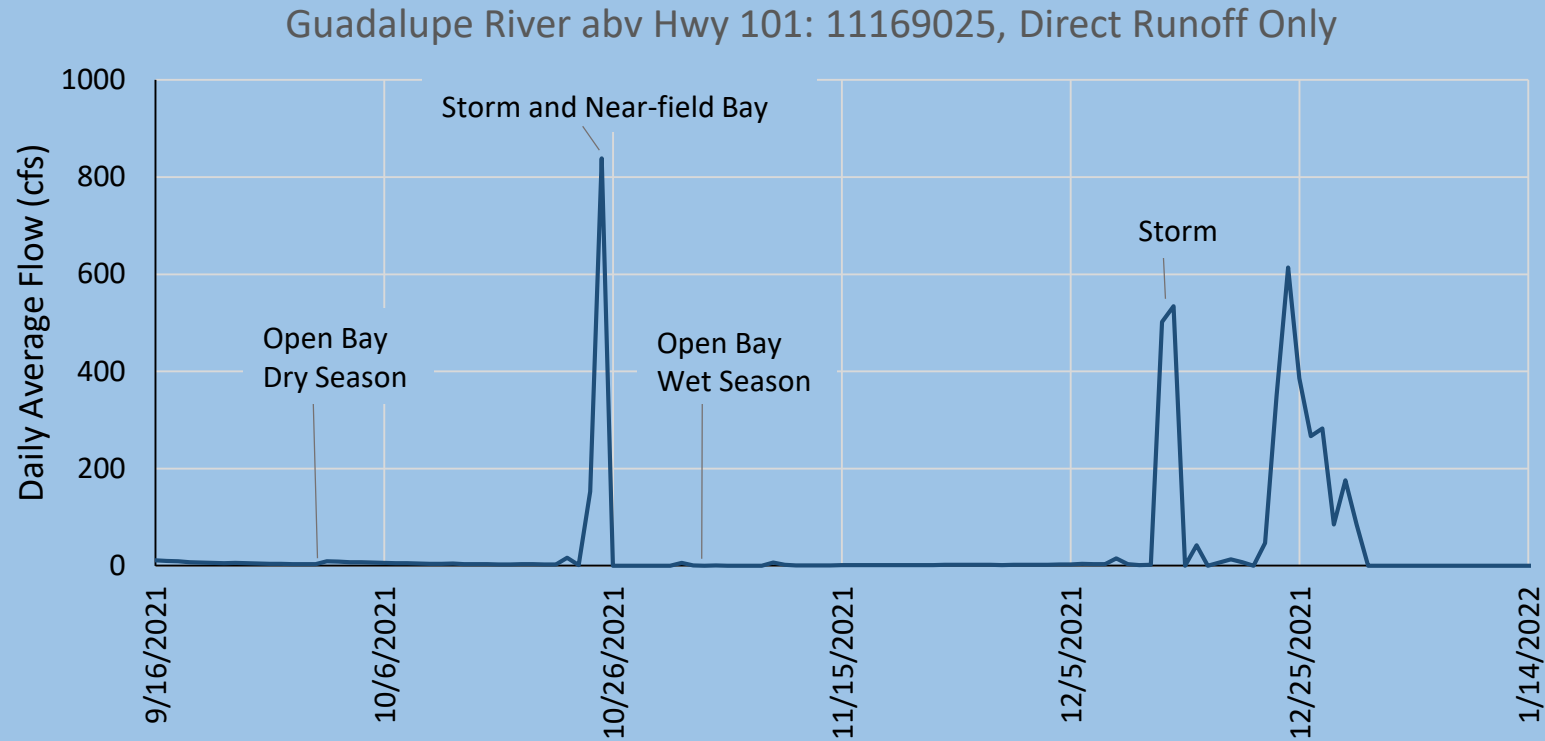
Adult 24-h LC<sub>50</sub> = 1,960 ng/L



Coho (extirpated)  
LC<sub>50</sub> range = 41-110 ng/L

Interim PNEC: 10 ng/L  
(AF = 100; 96-h LC<sub>50</sub>)

# Stormwater Exposure: Repeat Pulses

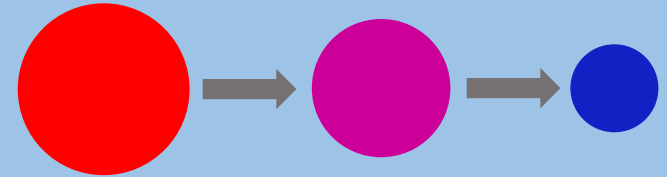


- Toxicity depends on exposure duration
- Storm event runoff times vary and can be multi-day
- 6PPD-quinone toxicokinetics and toxicodynamics still not well understood



# Conclusions

- Estimated tire microplastic emissions 2-3 kg/capita annually
  - 2% to 6% may reach San Francisco Bay
- Tire contaminants reach detectable concentrations
  - in SF Bay water near stormwater discharge locations
  - in the center of the Bay, even with dilution from mixing
- 6PPD-quinone reaches concentrations that may be of concern for local steelhead and rainbow trout

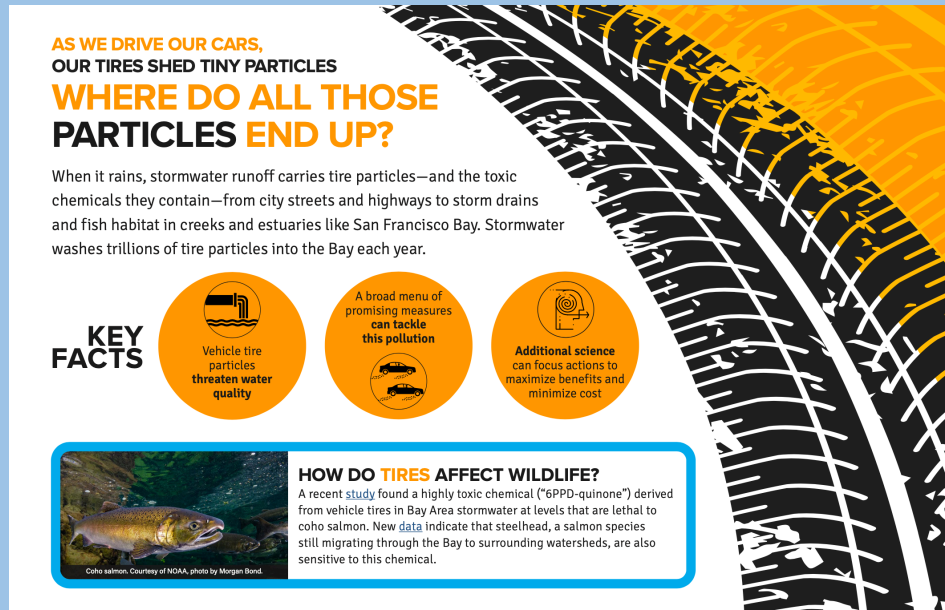


Uh oh! I don't  
need more  
stressors!



# Want to learn more?

## 2022 Factsheet




**AS WE DRIVE OUR CARS, OUR TIRES SHED TINY PARTICLES**  
**WHERE DO ALL THOSE PARTICLES END UP?**

When it rains, stormwater runoff carries tire particles—and the toxic chemicals they contain—from city streets and highways to storm drains and fish habitat in creeks and estuaries like San Francisco Bay. Stormwater washes trillions of tire particles into the Bay each year.

**KEY FACTS**

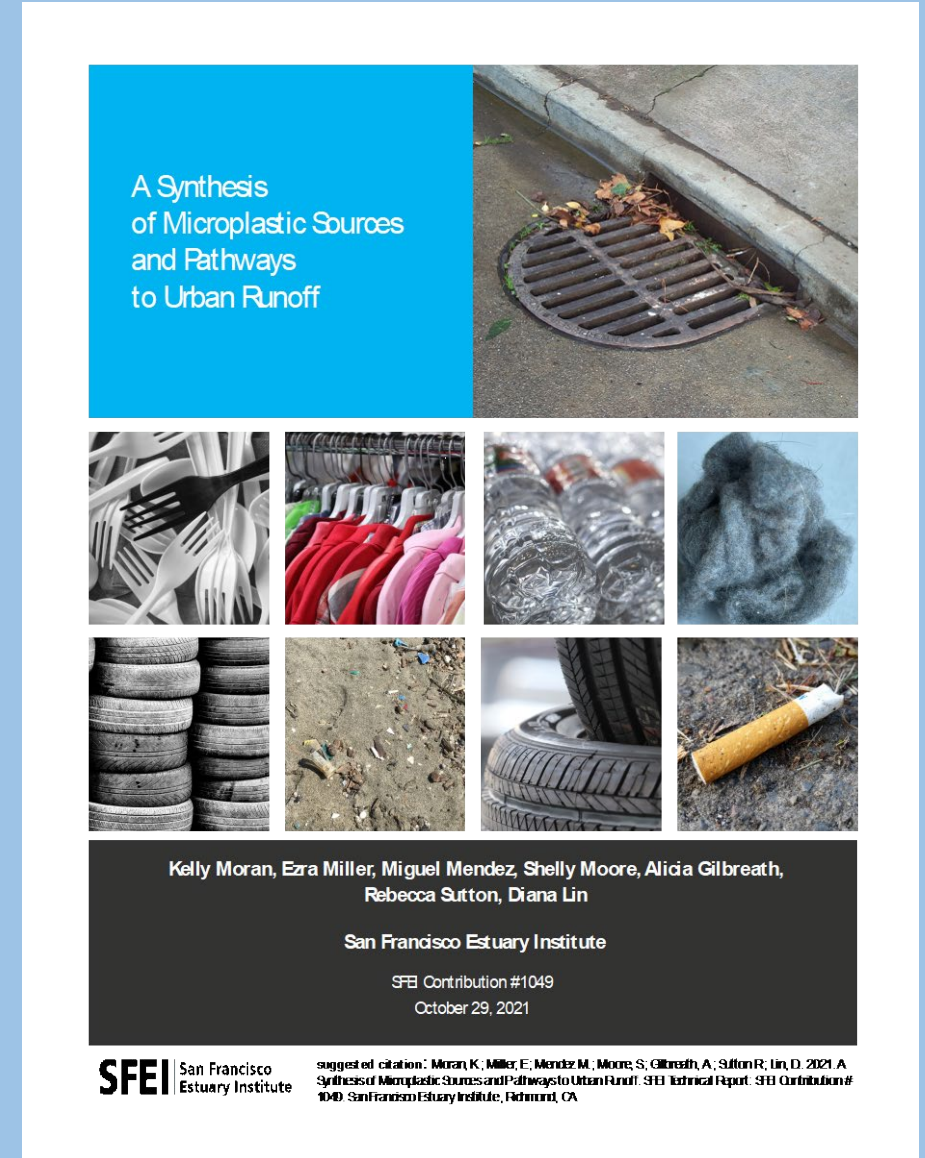
- Vehicle tire particles threaten water quality
- A broad menu of promising measures can tackle this pollution
- Additional science can focus actions to maximize benefits and minimize cost

**HOW DO TIRES AFFECT WILDLIFE?**  
A recent [study](#) found a highly toxic chemical ("6PPD-quinone") derived from vehicle tires in Bay Area stormwater at levels that are lethal to coho salmon. New [data](#) indicate that steelhead, a salmon species still migrating through the Bay to surrounding watersheds, are also sensitive to this chemical.



Report available upon request:  
**Tire Wear: Emissions Estimates and Market Insights to Inform Monitoring Design**

## Transport Conceptual Model & Mitigation Strategies



**A Synthesis of Microplastic Sources and Pathways to Urban Runoff**

Kelly Moran, Ezra Miller, Miguel Mendez, Shelly Moore, Alicia Gilbreath, Rebecca Sutton, Diana Lin

San Francisco Estuary Institute

SFEI Contribution #1049  
October 29, 2021

**SFEI** San Francisco Estuary Institute

suggested citation: Moran, K.; Miller, E.; Mendez, M.; Moore, S.; Gilbreath, A.; Sutton, R.; Lin, D. 2021. A Synthesis of Microplastic Sources and Pathways to Urban Runoff. SFEI Technical Report. SFEI Contribution # 1049. San Francisco Estuary Institute, Richmond, CA.

# Questions?

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