

Table 4-2. Studies of 6PPD and 6PPD-q concentrations in stormwater

Location	Information	Concentration (varies by study)	Lab Instrumentation	Detection Limit
New Territories and Kowloon, Hong Kong (Cao et al. 2022)	Nine urban runoff water samples were collected in a dense traffic urban area in Kowloon, Hong Kong, in August 2021. Samples were analyzed for PPD and PPD-q.	The concentrations of 6PPD and 6PPD-q in stormwater were found to be [median (range), µg/L]: 6PPD: 0.32 (0.21–2.71) 6PPD-q: 1.12 (0.21–2.43)	UHPLC-MS	IQL (ng/mL): 6PPD: 0.035 6PPD-q: 0.023
Norway (Kryuchkov et al. 2023)	Samples were collected from tunnel wash runoff (n=4) and the tunnel runoff treatment plant (n=3). One artificial turf runoff sample (from a soccer field) and one puddle sample were also collected. Samples were analyzed for 6PPD-q.	The concentrations of 6PPD-q in various media were found to be [range, ng/L]: Tunnel wash runoff: 49.5–143 (n=4) Wastewater treatment facility near tunnel: 7.00–23.0 (n=2) Culvert at treatment facility: <LOQ (n=1) Road puddle: 258 (n=1) Artificial turf runoff: 159 (n=1)	LC-MS/MS	LOQ: 5 ng/L
Canada (Challis et al. 2021)	Sampling was conducted in the City of Saskatoon in Canada. Snowmelt samples were collected in 2019 and 2020 from the city's snow dumps. Stormwater samples were collected at seven outfalls representing residential, industrial, and retail developments. Nine surface-water samples were collected from the South Saskatchewan River. Samples were analyzed for 6PPD-q.	The concentrations of 6PPD-q were found to be [mean (range), ng/L]: Stormwater—2019: 593 (86–1,400) Snowmelt—2019: 367 (74–756) Snowmelt—2020: 81 (15–172)	UHPLC-MS	LOD: 1.2 ng/mL LOQ: 3.3 ng/mL
Canada (Monaghan et al. 2021)	Surface-water (n=2) and stormwater (n=4) samples were collected in May and June of 2021 in Nanaimo, British Columbia, Canada, and analyzed for 6PPD-q. The analytical method provides semiquantitative results of 6PPD-q.	The concentrations of 6PPD-q were found to be [range, ng/L]: Stormwater: 48–5,580	Direct sampling tandem mass spectrometry method for <i>semiquantitative</i> 6-PPD-q determinations using CP-MIMS with a thin PDMS capillary hollow fiber membrane	LOD: 8 ng/mL
Michigan (Nedrich 2022)	The Michigan Department of Environment performed a preliminary investigation of 6PPD-q occurrence. Seventeen surface-water samples were collected in rivers or creeks adjacent to roadways and five samples were collected from roadway puddles. Surface-water samples included two from known salmon spawning rivers and two from locations downstream of industrial crumb-rubber storage facilities. Samples were collected within 35 hours of a significant rain event. Two of the 17 surface-water samples had detections of 6PPD-q, whereas 100% of puddle samples had detectable levels of 6PPD-q.	The concentrations of 6PPD-q were found to be [range, ng/L]: Puddles: 54–660	LC-MS	MDL: 3 ng/L
Seattle, Los Angeles, San Francisco (Tian et al. 2022)	Roadway runoff and roadway runoff-impacted receiving water samples were reanalyzed for 6PPD-q using a commercial standard. Concentrations were visually approximated from the boxplots provided in the publication.	The concentrations of 6PPD-q in stormwater were found to be [µg/L]: Stormwater: approximately 1.3 (maximum)	UHPLC-MS with SPE	LOQ: 5.1 ng/L

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Pearl River Delta, China (H.-Y. Zhang et al. 2023)	Surface runoff samples (courtyard [n=2], roadway [n=3], and farmland [n=2]) were collected in Dongguan and Huizhou across multiple events in 2015. Three Guangzhou WWTP influents and effluents were sampled in 2016. Surface-water samples from the Zhujiang (n=13) and Dongjiang (n=13) rivers were collected in 2015. Six samples were collected from a DWTP in Guangzhou in 2020. All samples were analyzed for 23 tire additives and their transformation products, including 6PPD-q and 6PPD.	The concentrations of 6PPD and 6PPD-q were found to be [median (range), ng/L]: 6PPD: Roadway runoff: 3.05 (0.41–7.52) Courtyard runoff: 0.89 (0.19–1.10) Farmland runoff: ND 6PPD-q: Roadway runoff: 576 (38.5–1,562) Courtyard runoff: 51.6 (6.03–875) Farmland runoff: 0.73 (0.53–5.58)	UHPLC-MS	6PPD: LOD: 0.04 ng/L LOQ: 0.12 ng/L 6PPD-q: LOD: 0.05 ng/L LOQ: 0.17 ng/L
Guangzhou, China (R. Zhang et al. 2023)	Surface-water (n=19), groundwater (n=43), and stormwater (n=10) samples were collected along the Liuxi River and analyzed for p-phenylenediamines, including 6PPD and 6PPD-q. Suspended particles from stormwater samples were also analyzed. As expected, 6PPD was only detected in the particle phase.	The concentrations of 6PPD and 6PPD-q were found to be [median (range), ng/L]: 6PPD: Stormwater: ND Suspended particles: 0.20 (ND–0.74) 6PPD-q: Stormwater: 0.34 (0.18–1.42) Suspended particles: 0.01 (ND–0.07)	UHPLC-MS/MS	6PPD: MDL: 0.048 ng/L MQL: 0.160 ng/L 6PPD-q: MDL: 0.029 ng/L MQL: 0.098 ng/L
Seattle Area (Zhao et al. 2023)	Samples from roadway runoff (n=4; grab samples) and roadway-impacted creek water (n=5; composite samples) were collected and analyzed for 6PPD and 6PPD-q. Both compounds were detected in 100% of the samples. 6PPD measurements were considered semiquantitative given the compound's instability in water.	The concentrations of 6PPD and 6PPD-q in stormwater were found to be [mean \pm SD, ng/L]: 6PPD: Stormwater: 75 \pm 40 6PPD-q: Stormwater: 140 \pm 60	LC-MS/MS	6PPD: LOD—Creek: 3.3 ng/L LOQ—Creek: 4.9 ng/L LOD—Runoff: 2.4 ng/L LOQ—Runoff: 3.9 ng/L 6PPD-q: LOD—Creek: 1.2 ng/L LOQ—Creek: 3.1 ng/L LOD—Runoff: 2.1 ng/L LOQ—Runoff: 5.7 ng/L

Notes: $\mu\text{g/L}$ =micrograms per liter, CP-MIMS=condensed phase membrane introduction mass spectrometry, DWTP=drinking water treatment plant, IQL=instrument quantification limit, LC-MS=liquid chromatography / mass spectrometry, LC-MS/MS=liquid chromatography / tandem mass spectrometry, LOD=limit of detection, LOQ=limit of quantitation, MDL=method detection limit, MQL=method quantification limit, ND=nondetect, ng/L=nanograms per liter, PDMS=polydimethylsiloxane, PPD=para-phenylenediamines, PPD-q=para-phenylenediamines-quinone, SPE=solid-phase extraction, UHPLC-MS=ultra-high-performance liquid chromatography–mass spectrometry, UHPLC-MS/MS=ultra-high-performance liquid chromatography–tandem mass spectrometry, WWTP=wastewater treatment plant

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