Table 4-3. Studies of 6PPD and 6PPD-q concentrations in wastewater, water treatment plants, and tap water

Location	Information	Concentration (varies by study)	Method	Detection Limit
WWTPs in Hong Kong (Cao et al. 2023)	Tested influent, effluent, and biosolids at four WWTPs in Hong Kong for PPD and PPD-q, including 6PPD and 6PPD-q.	The concentrations of 6PPD and 6PPD-q were found to be [median (range)]: 6PPD: Influent (raw): 12 (1.1–59) ng/L Effluent (treated): 0.30 (<LOQ-15) ng/L Biosolids: 5.5 (2.1–71) ng/g 6PPD-q: Influent (raw): 53 (1.9–470) ng/L Effluent (treated): 3.4 (1.1–37) ng/L Biosolids: 6.4 (2.6–7.3) ng/g	Extraction with DCM, Envi-carb SPE, HPLC-MS	6PPD: LOQ—influent: 0.12 ng/L LOD—influent: 0.037 ng/L LOQ—other: 0.06 ng/L LOD—other: 0.018 ng/L LOQ—biosolids: 0.31 ng/g LOD—biosolids: 0.092 ng/g 6PPD-q: LOQ—influent: 0.02 ng/L LOD—influent: 0.005 ng/L LOQ—other: 0.01 ng/L LOD—other: 0.002 ng/L LOQ—biosolids: 0.04 ng/g LOD—biosolids: 0.012 ng/g
WWTPs and Drinking Water Treatment Plants in Ontario (Johannessen and Metcalfe 2022)	Samples were collected at the influent and effluent of four WWTPs and two DWTPs in Ontario and analyzed for 6PPD-q. Removal efficiencies of 6PPD-q varied by WWTP, and in two WWTPs, the effluent mass exceeded that in the influent.	The concentrations of 6PPD-q were found to be [range, ng]: WWTP influent (raw): 64.8 ± 5.3–145.7 ± 46.7 WWTP effluent (treated): <LOD–446.5 ± 37.7 DWTP influent (raw) and effluent (treated): ND	UHPLC-HRMS	LOQ: 0.5 ng/mL
Influent and Effluent from WWTP in Leipzig Germany (Maurer et al. 2023)	Influent and effluent of a WWTP in Germany were collected at 24-hour intervals during snow melting. Samples were analyzed for various chemicals, including 6PPD-q; 6PPD was not included.	The concentrations of 6PPD-q in WWTP were found to be [mean (range), ng/L]: Influent (raw): 777 (592–1,100) Effluent (treated): 50 (41–66)	LC-HRMS	MDL (ng/L): 6PPD: 60 6PPD-q: 4
Influent and Effluent from five WWTPs in Malaysia and Sri Lanka (R. Zhang et al. 2023)	Tested influent and effluent at three WWTPs in Malaysia (n=93) and two WWTPs in Sri Lanka (n=28). Samples were analyzed for 6PPD, 6PPD-q, and other PPD.	The concentrations of 6PPD and 6PPD-q in WWTP were found to be [median (range), ng/L]: 6PPD: Malaysia WWTP influent (raw): ND Malaysia WWTP effluent (treated): ND Sri Lanka WWTP influent (raw): ND Sri Lanka WWTP effluent (treated): ND 6PPD-q: Malaysia WWTP influent (raw): ND Malaysia WWTP effluent (treated): ND (ND–0.11) Sri Lanka WWTP influent (raw): ND (ND–0.37) Sri Lanka WWTP effluent (treated): ND (ND–0.37)	LC-MS/MS	LOQ (ng/L): 6PPD: 0.120 6PPD-q: 0.098
Drinking water in Singapore (Marques dos Santos and Snyder 2023)	Drinking water samples were collected from 20 buildings in Singapore ranging in age from seven to 44 years. Samples were analyzed for various tire-related compounds, including 6PPD and 6PPD-q.	The concentrations of 6PPD and 6PPD-q were found to be [median (range), ng/L]: 6PPD: <10 (approximated based on boxplot; 25% detection frequency) 6PPD-q: ND	LC-MS/MS	6PPD: LOD: 0.075 ng/mL MRL: 0.94 ng/L 6PPD-q: LOD: 0.050 ng/mL MRL: 0.61 ng/L

Table 4-3. Studies of 6PPD and 6PPD-q concentrations in wastewater, water treatment plants, and tap water

Location	Information	Concentration (varies by study)	Method	Detection Limit
Pearl River Delta, China (H.-Y. Zhang et al. 2023)	Surface runoff samples (courtyard [n=2], road [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: WWTP influent (raw): ND WWTP effluent (treated): ND DWTP (all samples): ND 6PPD-q: WWTP influent (raw): 14.2 ± 0.80 to 69.8 ± 2.40 WWTP effluent (treated): ND to 2.09 ± 0.16 DWTP source water: 0.25 DWTP (all other samples): ND	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
Canada (Johannessen, Helm, and Metcalfe 2021)	Surface-water samples were collected from the Don River and Highland Creek during 2020 and included grab and composite samples. Samples were also collected upstream, downstream, and immediately below the effluent outfall of a WWTP. Samples were analyzed in triplicate for tire-related compounds, including 6PPD and 6PPD-q.	The concentrations of 6PPD and 6PPD-q were found to be [mean $\pm$ SD, µg/L]: 6PPD: WWTP effluent (treated): ND Upstream and downstream of WWTP: ND 6PPD-q: WWTP effluent (treated): 0.05 ± 0.02 Upstream and downstream of WWTP: ND	UHPLC-HRMS	6PPD: LOD: NR LOQ: NR 6PPD-q: LOD: NR LOQ: 0.0065 µg/L
Leipzig, Germany (Seiwert et al. 2022)	As part of a study that included a series of laboratory ozonation experiments to evaluate the abiotic transformation of 6PPD, sampling of the influent and effluent of a WWTP (during snow melt, rainfall event, and dry conditions) was conducted. Samples were analyzed for the presence of a range of tire- and road-wear particles and transformation products, including 6PPD and 6PPD-q. Concentrations of 6PPD were reported as 6PPD and its transformation products.	The concentrations of 6PPD + transformation products and 6PPD-q were found to be [mean $\pm$ SD, µg/L]: 6PPD + transformation products: Snowmelt—influent (raw): 4.4 Snowmelt—effluent (treated): 2.4 Rainfall—influent (raw): 14.3 Rainfall—effluent (treated): 11.2 Dry weather—influent (raw): 0.9 Dry weather—effluent (treated): 0.3 6PPD-q: Snowmelt—influent (raw): 0.105 ± 0.037 Snowmelt—effluent (treated): ND Rainfall—influent (raw): 0.052 ± 0.022 Rainfall—effluent (treated): ND Dry weather—influent (raw): ND Dry weather—effluent (treated): ND	UHPLC-HRMS/ UHPLC-TOF-MS	LOQ (ng/L): 6PPD: 100 6PPD-q: 25

Notes: µg/L=micrograms per liter, DCM=dichloromethane, DWTP=drinking water treatment plant, HPLC-MS=high–performance liquid chromatography–mass spectrometry, LC-HRMS=liquid chromatography / high-resolution mass spectrometry, 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, MRL=method reporting limit, ND=nondetect, ng=nanogram, ng/g=nanogram per gram, ng/L-nanograms per liter, PPD=para-phenylenediamines, PPD-q=para-phenylenediamines-quinones, SPE=solid-phase extraction, UHPLC-HRMS=ultra-high–performance liquid chromatography–high-resolution mass spectrometry, UHPLC-MS=ultra-high–performance liquid chromatography–mass spectrometry, UHPLC-TOF-MS=ultra-performance liquid chromatography–time-of-flight–mass spectrometry, WWTP=wastewater treatment plant

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