

Environmental Concentrations

Few studies have assessed levels of TBB, TBPH, TCPP, TPP, and V6 in Washington State's environment. There were no studies found that analyzed IPTPP in environmental samples. The following paragraphs describe the studies that have tested environmental samples in Washington State for at least one of the flame retardants on the HB2545 list. More information on the concentrations of the individual flame retardants reported by these studies can be found in the following section and are summarized in Table 1. Environmental levels found in Washington are discussed in the context of relevant data from other areas of North America, where available. European studies were used when no North American studies were available.

Overview of Washington Studies

Local Source Control study: Ecology measured TBB, TBPH, TCPP, TPP, and V6 in stormwater and sediment collected from commercial drainages in Clark County in the spring and summer of 2017 (Medlen, 2018). The study collected a total of 13 stormwater samples and 30 sediment samples for analysis of a large suite of parameters to identify and prioritize drainages in need of source control actions.

USGS Lower Columbia River studies: The United States Geological Survey (USGS) analyzed environmental samples for TPP and TCPP in their investigations of emerging contaminants in the Lower Columbia River ecosystem. Alvarez et al. (2014) reported estimated water concentrations of TPP and TCPP derived from 8 polar organic chemical integrative sampler (POCIS) deployments in the Lower Columbia River between 2008 and 2010. Counihan et al. (2014) analyzed TPP and TCPP in 25 freshwater sediment samples collected along the Lower Columbia River in 2010 across a range of sediment depositional strata.

WA 10 lakes study (in prep): Ecology is currently conducting a study to evaluate concentrations of flame retardants in 10 waterbodies of Washington State (Mathieu, 2017). Surface water samples were collected from 8 urban lakes and 2 rural lakes in fall 2017 and spring 2018 for analysis of TPP, TCPP, and V6. Fish tissue was collected from 3 of the waterbodies (Lake Ozette, Lake Spokane, and Lake Washington) for analysis of TBB. Sediments were collected from the 10 lakes in spring 2018 for analysis of TPP, TCPP, V6, and TBB. The report for this data is expected to be published in 2019 (Mathieu in prep); however, provisional data from the study is included in the following sections.

Results

TCPP

Surface water

TCPP concentrations measured in Washington surface waters were in the range of <50-857 ng/L in urban/industrial stormwater (Medlen, 2018), <0.55-1.9 ng/L in the Lower Columbia River (Alvarez et al.,

2014), and <25-188 ng/L in urban lakes (Mathieu, in prep). Detection frequencies in all three Washington studies were low, with <40% of samples containing quantifiable amounts of TCPP. The exception to this was a higher detection frequency of TCPP in surface water samples collected from lakes in spring 2018 (Mathieu, in prep). Six out of ten samples (60%) collected in the spring contained TCPP above the quantitation limit. Venier et al. (2014) found similar results in surface water collected from the Great Lakes in 2012. TCPP was detected in 12 out of 23 (52%) of samples in the Great Lakes study, with concentrations ranging <LOQ (limit of quantitation)-17.0 ng/L and a median of 0.37 ng/L. Other studies in North America have shown higher detection frequencies and higher concentrations: 3.3-329 ng/L in rivers and lakes of New York (100% detection frequency) (Kim and Kannan, 2018) and <LOQ-2,010 ng/L in urban stream water in Toronto, Ontario (60% detection frequency) (Hao et al., 2018).

Sediment

TCPP has been detected infrequently in Washington sediments. None of the 25 sediment samples collected from the Lower Columbia River contained TCPP above detection limits (Counihan et al., 2014). Three out of ten samples (30%) collected from Washington lakes contained TCPP above quantitation limits, ranging from <1-388 ng/g dry weight (dw) (Mathieu, in prep.). Twenty three percent of sediment samples collected from urban/industrial catchments in Clark County contained TCPP, with concentrations ranging from <1.1-2,040 ng/g dw (Medlen, 2018). Maximum concentrations of TCPP measured in urban/industrial catchments in Washington were similar to sediments collected in industrial areas of Norway (2,080 ng/g dw) (Green et al., 2008). Overall, other studies in North America and Europe have shown much lower concentrations, though more frequent detections, of TCPP. Cao et al. (2017) measured TCPP in sediment collected from the Great Lakes in the range of <LOQ-3.37 ng/g dw (median: 0.33 ng/g dw).

Fish

No studies were found that measured TCPP in Washington State fish. Guo et al. (2017) reported TCPP concentrations in whole body lake trout and walleye collected from the Great Lakes in 2010 as ranging from 0.42-2.08 ng/g wet weight (ww). TCPP was largely undetected in a study of lake trout and walleye in Canadian waterbodies (McGoldrick et al., 2014).

TPP

Surface water

TPP was not detected in ambient surface waters collected in Washington (Alvarez et al., 2014; Mathieu in prep), but was detected frequently in the urban/industrial catchment stormwater collected in Clark County (Medlen, 2018). TPP was found in 92% of the urban/industrial stormwater samples at concentrations up to 83 ng/L, with a median of 30 ng/L. Other studies have reported TPP in waterbodies of North America – Great Lakes, Ontario urban streams, and New York waterbodies – at similar levels ranging from <LOQ-37 ng/L (Venier et al., 2014; Hao et al., 2018; Kim and Kannan, 2018).

Sediment

TPP was frequently detected in sediment samples collected from urban/industrial catchments (Medlen, 2018). Sixty seven percent of the urban/industrial sediment samples contained TPP, with concentrations ranging from <1.1- 36 ng/g dw. In lake sediments, 3 out of 10 samples (30%) contained TPP above quantitation limits (Mathieu, in prep.). TPP concentrations in the lake sediments ranged from

<0.3-33.9 ng/g dw (Mathieu, in prep.). In the Lower Columbia River, 4 out of 25 sediment samples contained TPP (range: non-detect-15.1 ng/g weight basis not reported). No sediment samples collected in the San Francisco Estuary contained TPP above a reporting limit of 0.01 ng/g dw (Klosterhaus et al., 2012).

Fish

No Washington studies reporting TPP levels in fish tissue were identified. In trout and walleye collected from the Great Lakes in 2010, 79% of whole body samples contained TPP, ranging from <LOQ-280 ng/g lipid weight (lw) (median: 6.7 ng/g lw) (Guo et al., 2017). In trout and walleye collected from 19 lakes across Canada in 2009/2010, only one sample contained TPP (McGoldrick et al., 2014). The concentration of that sample was not reported.

TBB

Surface water

TBB was not detected in urban/industrial stormwater collected in Washington at a reporting limit of 50 ng/L (Medlen, 2018). A Great Lakes study frequently detected TBB in surface water samples collected in 2012 (96% of samples, 22 out of 23) at much lower concentrations than the reporting limit for the Washington study (Venier et al., 2014). TBB concentrations in the Great Lakes samples ranged from <LOQ-0.021 ng/L (Venier et al., 2014). No other studies of TBB in surface water were identified.

Sediment

TBB was analyzed but not detected in urban/industrial sediments in Washington at reporting limits of 6.8-21.7 ng/g dw (Medlen, 2018) nor was TBB detected in lake sediments at reporting limits of 2-25 ng/g dw (Mathieu, in prep.). Similarly, TBB was also undetected in San Francisco Estuary sediments collected in 2007, at a reporting limit of 0.01 ng/g dw (Klosterhaus et al., 2012).

Fish

Of 12 freshwater fish tissue samples collected in Washington, no samples contained TBB above the detection limit of 3 ng/g ww (Mathieu in prep.). TBB was also undetected in freshwater and marine fish collected from the St. Lawrence River watershed, the Great Lakes, and the San Francisco Estuary collected between 2006 and 2012 (Houde et al., 2014; Guo et al., 2017; Klosterhaus et al., 2012). In Illinois streams and lakes, Widelka et al. (2016) reported TBB concentrations in common carp fillets of ND-73 ng/g lw and in largemouth bass fillets of ND-225 ng/g lw.

TBPH

Surface water

TBPH was not detected in urban/industrial stormwater collected in Washington at or above a reporting limit of 50 ng/L (Medlen, 2018). In surface water collected from the Great Lakes in 2012, TBPH was detected in 74% of the samples (17 out of 23) at concentrations much lower than the Washington reporting limit (range: <LOQ-0.014 ng/L) (Venier et al., 2014).

Sediment

TBPH was not detected in sediments collected in Washington urban/industrial catchments, at or above reporting limits of 13-43 ng/g dw (Medlen, 2018) nor in lake sediments at reporting limits of 2-25 ng/g dw (Mathieu, in prep.). TBPH was also not detected in sediments collected from the San Francisco Estuary, at a lower reporting limit of 0.20 ng/g dw (Klosterhaus et al., 2012).

Fish

No studies were found that analyzed TBPH in fish collected from Washington waterbodies. In Illinois waterbodies sampled in 2013/2014, TBPH was reported in common carp fillets from non-detect (ND)-64 ng/g lw (median: <LOQ) and in largemouth bass fillets from ND-122 ng/g lw (median: <LOQ) (Widelka et al., 2016). TBPH was not detected in lake trout and walleye collected from the Great Lakes in 2010 (Guo et al., 2017). In the St. Lawrence River watershed between 2008 and 2012, Houde et al. (2014) reported no detections of TPBH in whole body yellow perch, while TBPH was detected in 64% and 40% of northern pike and muskellunge liver samples, respectively. Houde et al. (2014) reported a mean TBPH concentration of 5.4 ng/g lw in northern pike liver tissue and a range in TBPH concentrations of <LOQ-13 ng/g lw.

V6

Surface water

V6 was detected at low levels (range: <0.05-1.52 ng/L) in lake surface water samples collected in Washington (Mathieu in prep.). Detection frequencies were higher in spring 2018 (7 out of 10 samples) compared to fall 2017 (2 out of 10 samples). In Washington urban/industrial stormwater, V6 was detected in 1 out of 13 samples, at 10 ng/L. No V6 was detected in the other stormwater samples at or above a 10 ng/L reporting limit (Medlen, 2018). No other North American studies in the literature were found to report V6 in surface water.

Sediment

In urban/industrial sediment samples collected in Washington, V6 was detected infrequently (17% of samples) at concentrations ranging from <1.1-7.1 ng/g dw and a median of <1.5 ng/g dw (Medlen, 2018). In lake sediments, 4 out of 10 samples (40%) contained V6 above quantitation limits, with concentrations ranging from <0.3-4.92 ng/g dw (Mathieu, in prep.). V6 was also infrequently detected in studies conducted in Norway. Leonards et al. (2011) reported no detections of V6 in Norwegian sediments collected in 2010, and Green et al. (2008) reported one detection out of 8 samples (13%), at 36 ng/g dw, in sediment samples collected in 2003/2007 near a car demolishing plant.

Fish

No studies were found that analyzed V6 levels in fish collected from Washington waterbodies. No North American studies were identified either. In Norway, liver and/or fillet samples of burbot, Atlantic cod, and brown trout were analyzed for V6 but all samples were below detection limits (Leonards et al., 2011).

IPTPP

No environmental data for IPTPP was found for Washington State or elsewhere in current scientific literature.

Table 1. Concentrations of Flame Retardants in Environmental Samples Collected in Washington State.

Analyte	Location	Sample Matrix	Sample Type	Collection Year	n	Detection Frequency	Min	Max	Median	Unit	Reference
TCPP	Clark County, urban/industrial	stormwater	outfall	2017	13	31%	< 50	857 J	< 100	ng/L	Medlen, 2018
TCPP	10 WA lakes*	freshwater	surface grab, fall	2017	10	10%	< 25	179	< 25	ng/L	Mathieu, in prep.
TCPP	10 WA lakes*	freshwater	surface grab, spring	2018	10	60%	ND	188 J	---	ng/L	Mathieu, in prep.
TCPP	Lower Columbia River	freshwater	POCIS	2008-2010	8	38%	< 0.55	1.9	< 0.55	ng/L	Alvarez et al., 2014
TCPP	Lower Columbia River	freshwater sediment	surface	2010	25	0%	ND	ND	---	ng/g dw	Counihan et al., 2014
TCPP	Clark County, urban/industrial	freshwater sediment	0-12 cm, catchment	2017	30	23%	< 1.08	2,040 E	6.65	ng/g dw	Medlen, 2018
TCPP	10 WA lakes*	freshwater sediment	0-2 cm	2018	10	30%	< 1	388	< 12	ng/g dw	Mathieu, in prep.
TPP	Clark County, urban/industrial	stormwater	outfall	2017	13	92%	< 8	83	30 J	ng/L	Medlen, 2018
TPP	10 WA lakes*	freshwater	surface grab, fall	2017	10	0%	< 0.6	< 2.7	---	ng/L	Mathieu, in prep.
TPP	10 WA lakes*	freshwater	surface grab, spring	2018	10	0%	< 0.5	< 2.6	< 1	ng/L	Mathieu, in prep.
TPP	Lower Columbia River	freshwater	POCIS	2008-2010	34	0%	< 0.59	< 7.2	---	ng/L	Alvarez et al., 2015
TPP	Lower Columbia River	freshwater sediment	surface	2010	25	16%	ND	15.1	ND	ng/g dw	Counihan et al., 2014
TPP	Clark County, urban/industrial	freshwater sediment	0-12 cm, catchment	2017	30	67%	< 1.12	36.1	---	ng/g dw	Medlen, 2018
TPP	10 WA lakes*	freshwater sediment	0-2 cm	2018	10	30%	< 0.3	33.9	< 2	ng/g dw	Mathieu, in prep.
TBB	Clark County, urban/industrial	stormwater	outfall	2017	13	0%	< 50	< 50	---	ng/L	Medlen, 2018
TBB	Clark County, urban/industrial	freshwater sediment	0-12 cm, catchment	2017	30	0%	< 6.8	< 21.7	---	ng/g dw	Medlen, 2018
TBB	10 WA lakes*	freshwater sediment	0-2 cm	2018	10	0%	< 2	< 25	---	ng/g dw	Mathieu, in prep.
TBB	10 WA lakes*	freshwater fish	largemouth bass, fillet	2017	4	0%	< 3	< 3	---	ng/g ww	Mathieu, in prep.
TBB	10 WA lakes*	freshwater fish	largescale sucker, fillet	2017	4	0%	< 3	< 3	---	ng/g ww	Mathieu, in prep.
TBB	10 WA lakes*	freshwater fish	northern pikeminnow, fillet	2017	4	0%	< 3	< 3	---	ng/g ww	Mathieu, in prep.
TBPH	Clark County, urban/industrial	stormwater	outfall	2017	13	0%	< 50	< 50	---	ng/L	Medlen, 2018
TBPH	Clark County, urban/industrial	freshwater sediment	0-12 cm, catchment	2017	30	0%	< 13	< 43	---	ng/g dw	Medlen, 2018
TBPH	10 WA lakes*	freshwater sediment	0-2 cm	2018	10	0%	< 2	< 25	---	ng/g dw	Mathieu, in prep.
V6	Clark County, urban/industrial	stormwater	outfall	2017	13	8%	< 10	10	---	ng/L	Medlen, 2018
V6	10 WA lakes*	freshwater	surface grab, fall	2017	10	20%	< 0.5	1.3 J	< 0.5	ng/L	Mathieu, in prep.
V6	10 WA lakes*	freshwater	surface grab, spring	2018	10	70%	ND	1.52 J	---	ng/L	Mathieu, in prep.
V6	Clark County, urban/industrial	freshwater sediment	0-12 cm, catchment	2017	30	17%	< 1.08	7.12	< 1.5	ng/g dw	Medlen, 2018
V6	10 WA lakes*	freshwater sediment	0-2 cm	2018	10	40%	< 0.3	4.92	---	ng/g dw	Mathieu, in prep.

POCIS = polar organic chemical integrative sampler. "<" = Analyte was not detected at or above the reported value; J = Analyte was positively identified. The reported result is an estimate; E = Reported result is an estimate because it exceeds the calibration range; ND = not detected.

* Provisional Data, subject to change.

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