Improvements in water quality by an integrated constructed wetland in Broomfield Park in the Pymmes Brook catchment

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1. INTRODUCTION

The Pymmes Brook is a short (13.1 km long) predominantly urban tributary of the River Lea that flows through the boroughs of Enfield, Barnet and Haringey in North London. It suffers from chronic and acute diffuse pollution issues, in particular discharges of raw sewage and from plumbing misconnected into the drainage network and flowing directly into the river rather than to a treatment works. In addition, oils, metals and other traffic pollutants wash off roads into the surface water drains and then to the rivers when it rains in a process known as road runoff.

Broomfield Park wetland in Enfield (fig 1) was constructed in June 2019 with the primary aim of improving water quality in the catchment. It is part of Coca-Cola's water stewardship strategy, Replenish, one aim of which is to return the equivalent amount of water used in drink production to nature and communities. The surface water drain (that drains a catchment area 34 hectares) that runs through the park was diverted into two purpose-built, planted wetland cells for treatment by natural wetland processes, thereby improving the water quality before it enters the Pymmes Brook. The cells were planted with the aid of local volunteers and Coca-Cola employees from the nearby bottling plant in Edmonton.

The wetland is also anticipated to deliver flood risk reduction to 36 downstream properties considered by the Environment Agency to be at significant risk of flooding and 267 properties at moderate risk of flooding (fig 2). This is achieved by catching and storing both rainfall and surface runoff (that would otherwise have been piped directly to the river) which is then slowly released into the river. Additional wetland benefits include increased amenity and biodiversity value with implications for health and wellbeing of local residents, and climate resilience.

This report presents the results of an assessment of water quality enhancements delivered by the newly completed wetland. Five paired water samples were taken from the inflow and outflow of the wetland between September 2019 and August 2000. Results indicate water quality improvements for the majority of parameters, including reclassification of ammonia and phosphate from 'poor' to 'moderate' according to the water quality standards of the Water Framework Directive (WFD).

Broomfield Park wetland was highly commended in the Susdrain Sustainable Urban Drainage (SuDS) Awards Small scale retrofit category, placing it in the top four initiatives of this kind nationwide. It was developed in partnership between the Coca-Cola Foundation, The Rivers Trust, WWF-UK, Thames21 and Enfield Council, supported by the Friends of Broomfield Park and the Pymmes BrookERS.

Figure 1: Broomfield Park wetland. Top: In Spring 2020. The first cell where water flows in is in the background, the second cell in the foreground; Bottom: In June 2020 showing emergent flowering vegetation important for amenity and biodiversity value.

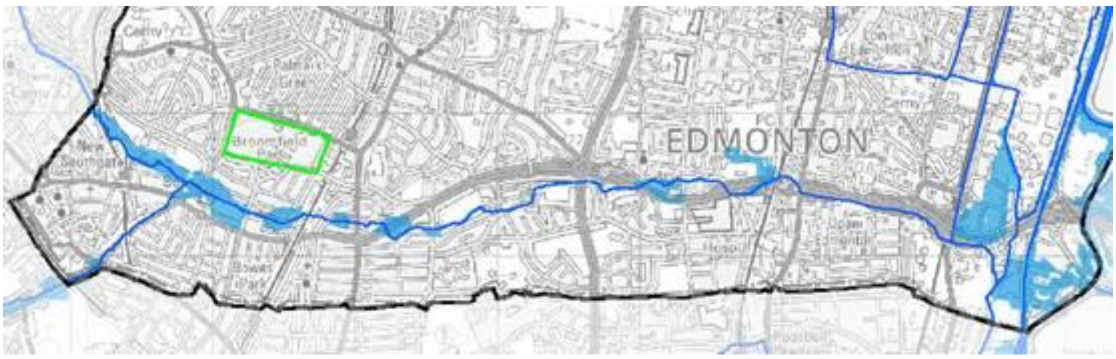

Figure 2: Fluvial flood risk (blue) in the Pymmes Brook catchment for a 1 in 100-year event incorporating climate change. Estimated number of properties at risk = 421. Broomfield Park is highlighted in green. The Pymmes Brook flows west to east and joins the River Lea at the bottom right.

2. SAMPLING AND METHODS

2.1 Water sampling

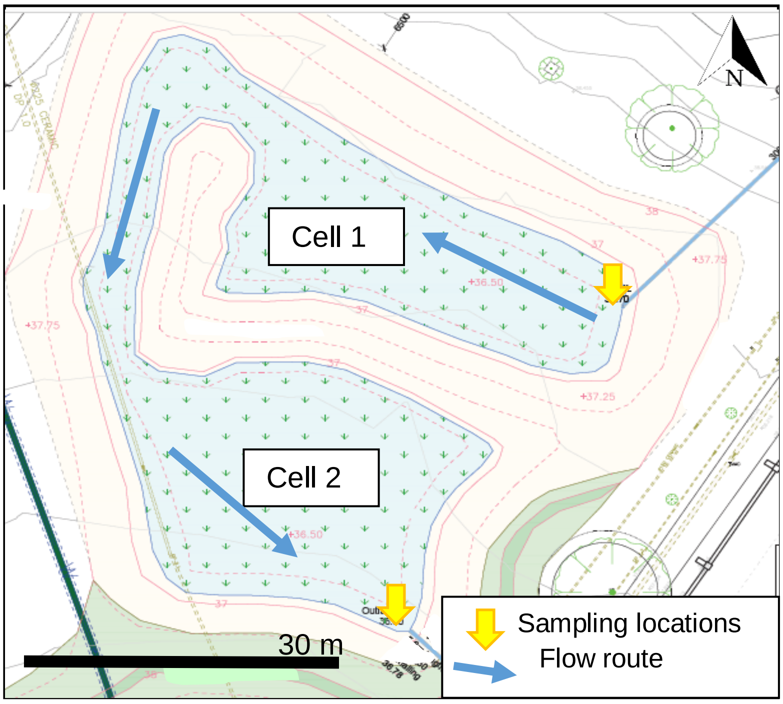

Figure 3: The sampling locations and flow route through Broomfield Park wetlands.

(Map adapted from the draft proposal, Enfield Council)

Figure 3 shows the two water sampling locations at the inflow and outflow of Broomfield Park wetlands. Samples were taken on 5 occasions (September and October 2019, March, May and August 2020) and were taken directly to a UKAS accredited laboratory (i2Analytical Ltd) for analysis of parameters listed in Table 1. Sampling only took place after a minimum of 72 hours without rain. This was because the impact of misconnected sewer pipes is usually diluted by rainfall and the ability of the wetland to treat pollution changes with residence time of water in the system. Resulting parameter concentrations are compared to water quality standards from the Water Framework Directive (WFD) and Environmental Quality standards (EQS), Table 2. Biological Oxygen Demand (BOD_5) was assessed using the Environment Agency General Quality Assessment Scheme (GQA). Statistical analysis of results was not possible due to the small number of samples.

For determination of the appropriate phosphate classification scale, all sites were determined to be type 3n based on altitude and mean alkalinity (WFD 2010).

Table 1: Parameters measured at the inflow and outflow of Broomfield Park wetland.

Type	**Determinands**
Nutrients	Phosphate (dissolved), nitrate (NO_3-N, the amount of nitrogen present as nitrate) and ammonia (NH_3-N ammoniacal nitrogen, nitrogen present as ammonia). • Nutrients enter the Pymmes Brook primarily from misconnected plumbing, including from raw sewage and laundry detergents. • Excess nutrients, especially phosphate, can cause eutrophication. In this process, nutrient excess stimulates overproduction of algae. After algal death, the abundance of organic matter and decomposing organisms depletes dissolved oxygen levels, depriving other aquatic life of oxygen and potentially leading to fish kills. • Ammonia may be present in two different forms. Its toxicity to fish is attributable mainly to the un-ionised NH_3 form which is suspected to be a leading cause of fish death.
BOD_5	Biological oxygen demand incubated over 5 days (sampled on Aug 2020 only). This is a proxy for the amount of organic pollution, such as sewage, in the water evaluated from the oxygen consumption of microorganisms involved in its natural breakdown.
Heavy metals (dissolved)	Copper, zinc, lead, cadmium. These are toxic at low concentrations and do not break down. Instead, they accumulate in the environment. In the Pymmes Brook, copper, zinc and lead likely derive from roof gutters and piping used in domestic plumbing. Zinc is also derived from vehicle tyres and brakes. All four metals are known to be present in road runoff. Metals tend to deposit in sediments, where they pose less risk to aquatic life provided, they are not disturbed. The dissolved (bioavailable) fraction in of most concern because it available for uptake by living organisms and tends to bioaccumulate in tissues.
BTEX	Benzene, toluene, ethylbenzene, xylene (known as BTEX) are constituents of crude oil and key components of a wide range of refined petroleum products including petrol and diesel and engine oils. They may be present in the wetland from road runoff.
PAHs	Polycyclic aromatic hydrocarbons (PAHs) are generated from incomplete combustion of organic compounds from vehicles and industry. They may accumulate in the wetland after traffic pollution washes off roads, for example Benzo(a)pyrene and Pyrene.

Table 2: Water quality parameters and modified WFD classification scales used by this report.
Nutrients, mg / L

Parameter	Very good	Good	Moderate	Poor	Source
Phosphate (dissolved)		≤ 0.2	0.3 – 0.8	> 0.8	1
Ammoniacal-nitrogen	≤ 0.6	0.7 – 1.1	1.2 – 2.5	> 2.5	2
Nitrate-nitrogen		≤ 10	10.1 – 20	> 30	2
Receiving water quality standards, metals (µg / L)					
Zinc	10.9				2
Copper	1.0				2
Cadmium	0.25				2
Lead	1.0				2

2.2 Flow measuring

In order to calculate the pollution load entering the wetland, surface flow was measured at the inflow and outflow. Passage of a float was timed travelling a 1 m distance. Triplicate float measurements were averaged and approximate discharge was calculated by the velocity-area method. Area was calculated from the diameter and water depth in the inflow/outflow pipes.

3. RESULTS AND DISCUSSION

3.1 Nutrients

There was a drop in mean concentrations of dissolved phosphate and ammonia between the inflow and outflow (fig 4). This resulted in an improvement in WFD water quality classification status from ‘poor’ to ‘moderate’ in both parameters and mean decreases of 69.3 % and 71.9 % respectively.

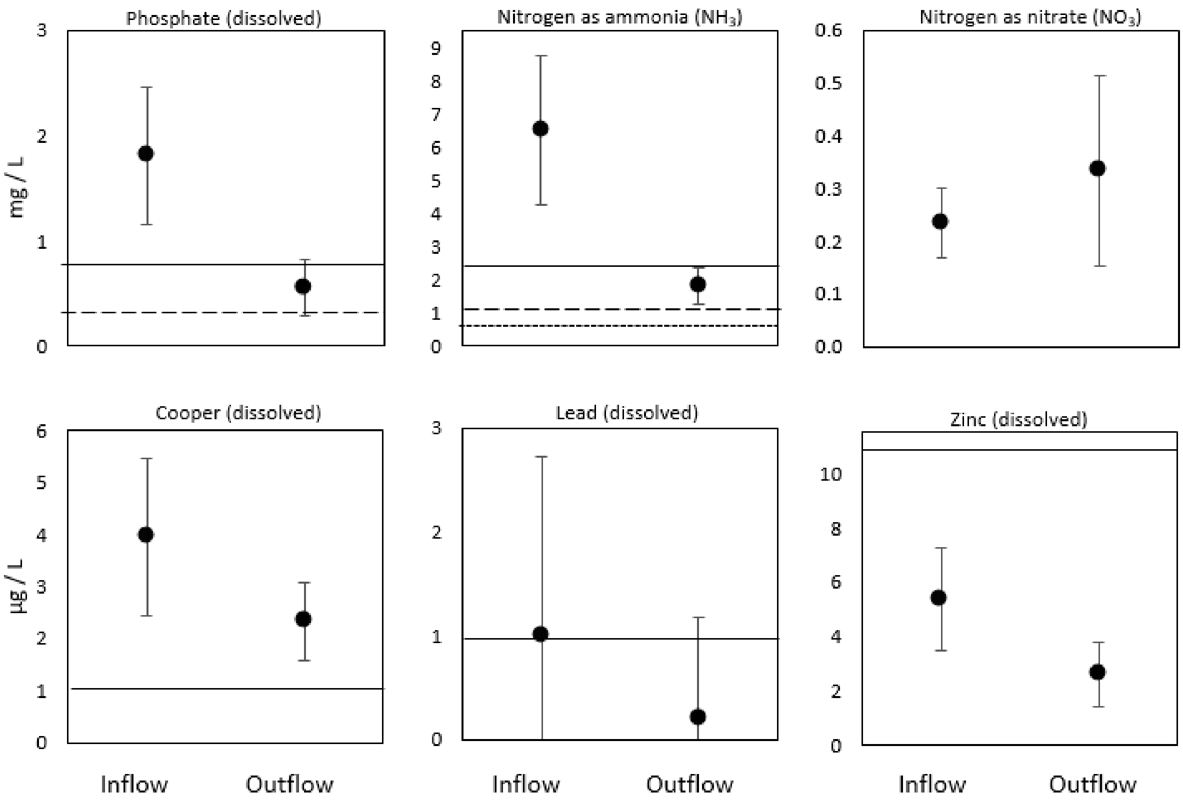

Figure 4: Mean (± SE) concentrations from the inflow and outflow of Broomfield Park wetlands from 5 paired water samples. Horizontal lines represent threshold standards in water quality from the WFD (nutrients (mg / L), top row) and annual average environmental quality standards (EQS, metals (µg /L), bottom row), simplified as poor (continuous line), moderate (dashed line), good (dotted line). Lead and zinc values at the outfall were below the analytical limit of detection on two occasions so minimum removal for these metals is represented, rather than actual removal.

Ammonia is the nitrogen compound that is most toxic to wildlife. It is converted into less harmful forms (nitrite then nitrate, the most stable form) by the nitrification process. One of the key services delivered by the wetland is slowing down the transfer time of water from the surface drainage network into the river. This removes ammonia by allowing nitrification to occur, which reduces the risk to aquatic life. The ammonia is ultimately converted to nitrate, which is why nitrate increases, rather than decreases, between the inflow and outflow of Broomfield Park wetland (fig 4). Nitrate at both the inflow and outflow is classified by the WFD as ‘good’ status, which means it is not posing significant eutrophication risk.

During the one occasion that BOD_5 was sampled, the amount of organic material in the water decreased by 84.1 % from 51.0 to 8.1 mg /l between the inflow and outflow. This indicates a marked reduction in organic pollution. BOD is not used for classifying water status (WFD), it is used for site-specific regulation, such as setting consented discharge limits into water courses. The biological oxygen demand at the inflow exceeded what is typically permitted from sewage treatment works [3], but was well within typical consent limits at the outfall.

3.2 Heavy metals

There was a drop in mean concentrations of dissolved metals between the inflow and outflow (fig 4), this is despite the fact that minimum removal, rather than actual removal is presented for lead and zinc. Minimum removal is presented because lead and zinc were below limit of detection (LOD: 0.2 µg / L and 0.5 µg / L respectively) at the outfall (September 2019 and August 2020), so actual removal compared to concentrations at the inflow could not be determined. Despite this, lead is reclassified as within permitted limits between the inflow and outflow, according to its environmental quality standard (EQS). Copper was present at detectable levels at the inflow and outflow on every sampling occasion, likely derived from copper piping used in domestic plumbing. Cadmium was only detected on one occasion. This was at the inflow in March 2020 (0.05 µg / L) and was below limit of detection (LOD: 0.02 µg / L) at the outfall on the same occasion.

The reduction in concentrations of all tested metals between the inflow and outflow indicates that metals are settling out in the wetland cells and becoming incorporated into the sediment and vegetation, where they may remain resident for a considerable time and pose lower risk to aquatic life in comparison to bioavailable metals dissolved in the water column.

3.3 Petroleum and other road runoff compounds

BTEX and PAHs were not present in detectable quantities on any of the 5 sampling visits (Appendix 1). Sampling occurred after prolonged dry periods during which there had been no runoff of traffic pollution from roads. Sampling during or immediately after rainfall events when water was flowing off the roads may have produced different results.

3.4 Pollution load/removal

Due to dense vegetation across the inflow and outflow of the wetland (fig 5) present during the majority of visits it was not possible to accurately estimate discharge. On the March 2020 visit the float was influenced by wind so was not representative of surface flow rate. Pollution loads are a snapshot in time that indicate the total amount of a pollutant entering the wetlands at the time of sampling. Sampling frequency was insufficient to calculate annual load estimates accurately.

Figure 5: Dense vegetation cover across the inflow (left) and outflow (right) of Broomfield Park wetland in Spring and Summer 2020.

4. RECOMMENDATIONS

Continued water sampling as the wetlands mature

- This investigation took place shortly after the construction phase of the wetlands and did not cover a full year to observe seasonal changes in wetland efficiency. It is important to continue monitoring the constructed wetlands as they mature to assess their ongoing effectiveness at different times of year and when factors such as sediment accumulation become important.
- Sampling associated with rainfall events would allow evaluation of the capacity of the wetland to deliver treatment of substances associated with road runoff pollution. This is highly relevant because an ongoing study has identified Broomfield Park as an opportunity for the treatment of road runoff [4]. This study investigated the risk of traffic pollution posed by the strategic road network in London and opportunities for its capture and treatment before it enters the river. Modelling by this study has indicated that Broomfield Park as ranked site 211 of 416 in London and 14 of 30 sites in Enfield Borough, based on the quantity of road runoff pollution it is estimated to receive via the surface water pipe network.

Real-time monitoring of water chemistry

- A limitation of this report is that spot samples were collected on less than a monthly basis. Spot samples tent to reflect average conditions rather than the extremes of pollution concentrations which are the most damaging to aquatic life. Real-time monitoring by probes and a flow meter installed in the inflow and outfall would allow high resolution, detailed assessment of wetland performance over a range of flow conditions and temporal scales, for example performance during drought and flood rainfall events and pollution removal efficiencies.

Installation of further constructed wetlands

- Broomfield Park has demonstrated its ability to deliver water quality improvements, however the Pymmes Brook catchment continues to suffer water quality issues. Construction of a distributed network of constructed wetlands would enable water quality improvement across the catchment by treating water pollution in greenspaces before it enters the river network. Suitable locations for the installation of further wetlands in the catchment have been identified both in the road runoff report highlighted above and in a community modelling investigation carried out previously by Thames21 that focused on pollution from misconnections [5].

5. REFERENCES

1 UKTAG 2012 A revised approach for setting WFD phosphorus standards
http://www.wfduk.org/sites/default/files/Media/Environmental%20standards/A%20revised%20approach%20for%20setting%20WFD%20phosphorus%20standards_101012.pdf

2 The Water Framework Directive (Standards and Classification) Directions (England and Wales) 2015
http://www.legislation.gov.uk/uksi/2015/1623/pdfs/uksiod_20151623_en.pdf

3 Environment Agency 2019 Waste water treatment works: treatment monitoring and compliance limits
https://www.gov.uk/government/publications/waste-water-treatment-works-treatment-monitoring-and-compliance-limits/waste-water-treatment-works-treatment-monitoring-and-compliance-limits#Maximum-compliance-limits-for-BOD-and-COD

4 GLA 2019 Road Runoff Water Quality Study Executive Summary
https://www.thames21.org.uk/improving-rivers/road-run-off/

5 Community Modelling: Water Quality in North London
https://www.thames21.org.uk/community-modelling/

6. APPENDIX

BTEX and PAH results were below limits of detection therefore not reported in the main text.

Compound type	Analytical parameter	Units	Limit of detection	Brember Road Manhole	Newton Park Wetland
Semi-volatile organic compounds (SVOCs), phenols and cresols	Aniline	mg/kg	0.1	< 0.1	< 0.1
	Phenol	mg/kg	0.2	< 0.2	< 0.2
	2-Chlorophenol	mg/kg	0.1	< 0.1	< 0.1
	Bis(2-chloroethyl)ether	mg/kg	0.2	< 0.2	< 0.2
	1,3-Dichlorobenzene	mg/kg	0.2	< 0.2	< 0.2
	1,2-Dichlorobenzene	mg/kg	0.1	< 0.1	< 0.1
	1,4-Dichlorobenzene	mg/kg	0.2	< 0.2	< 0.2
	Bis(2-chloroisopropyl)ether	mg/kg	0.1	< 0.1	< 0.1
	2-Methylphenol	mg/kg	0.3	< 0.3	< 0.3
	Hexachloroethane	mg/kg	0.05	< 0.05	< 0.05
	Nitrobenzene	mg/kg	0.3	< 0.3	< 0.3
	4-Methylphenol	mg/kg	0.2	< 0.2	< 0.2
	Isophorone	mg/kg	0.2	< 0.2	< 0.2
	2-Nitrophenol	mg/kg	0.3	< 0.3	< 0.3
	2,4-Dimethylphenol	mg/kg	0.3	< 0.3	< 0.3
	Bis(2-chloroethoxy)methane	mg/kg	0.3	< 0.3	< 0.3
	1,2,4-Trichlorobenzene	mg/kg	0.3	< 0.3	< 0.3
	2,4-Dichlorophenol	mg/kg	0.3	< 0.3	< 0.3
	4-Chloroaniline	mg/kg	0.1	< 0.1	< 0.1
	Hexachlorobutadiene	mg/kg	0.1	< 0.1	< 0.1
	4-Chloro-3-methylphenol	mg/kg	0.1	< 0.1	< 0.1
	2,4,6-Trichlorophenol	mg/kg	0.1	< 0.1	< 0.1
	2,4,5-Trichlorophenol	mg/kg	0.2	< 0.2	< 0.2
	2-Chloronaphthalene	mg/kg	0.1	< 0.1	< 0.1
	Dimethylphthalate	mg/kg	0.1	< 0.1	< 0.1
	2,6-Dinitrotoluene	mg/kg	0.1	< 0.1	< 0.1
	Acenaphthene	mg/kg	0.05	< 0.05	< 0.05
	2,4-Dinitrotoluene	mg/kg	0.2	< 0.2	< 0.2
	4-Chlorophenyl phenyl ether	mg/kg	0.3	< 0.3	< 0.3
	Diethyl phthalate	mg/kg	0.2	< 0.2	< 0.2
	4-Nitroaniline	mg/kg	0.2	< 0.2	< 0.2
	Azobenzene	mg/kg	0.3	< 0.3	< 0.3
	Bromophenyl phenyl ether	mg/kg	0.2	< 0.2	< 0.2
	Hexachlorobenzene	mg/kg	0.3	< 0.3	< 0.3
	Dibutyl phthalate	mg/kg	0.2	< 0.2	< 0.2
	Butyl benzyl phthalate	mg/kg	0.3	< 0.3	< 0.3
	Dibenz(a,h)anthracene	mg/kg	0.05	< 0.05	< 0.05

Compound type	Analytical parameter	Units	Limit of detection	Brember Road Manhole	Newton Park Wetland
SVOCs – semi quantified (TIC – total ion chromatogram method)	Naphthalene, 1,6,7-trimethyl-	mg/kg	N/A	-	0.00002
	Benzo[e]pyrene	mg/kg	N/A	-	0.015
	Naphthalene, 2,3-dimethyl-	mg/kg	N/A	-	0.003
	Naphthalene, 1,4-dimethyl-	mg/kg	N/A	-	0.0002
	Naphthalene, 2,6-dimethyl-	mg/kg	N/A	-	0.0004
	9H-Fluorene, 2-methyl-	mg/kg	N/A	-	0.07
	Dibenzothiophene	mg/kg	N/A	-	0.02
	11H-Benzo[b]fluorene	mg/kg	N/A	-	0.003

Compound type	Analytical parameter	Units	Limit of detection	Brember Road Manhole	Newton Park Wetland
Phenols (analysis by HPLC method)	Catechol	mg/kg	0.1	< 0.10	< 0.10
	Resorcinol	mg/kg	0.1	< 0.10	< 0.10
	Cresols (o-, m-, p-)	mg/kg	0.3	< 0.30	< 0.30
	Total Naphthols (sum of 1- and 2- Naphthol)	mg/kg	0.2	< 0.20	< 0.20
	2-Isopropylphenol	mg/kg	0.1	< 0.10	< 0.10
	Phenol	mg/kg	0.1	< 0.10	< 0.10
	Trimethylphenol (2,3,5-)	mg/kg	0.1	< 0.10	< 0.10
	Total Xylenols and Ethylphenols	mg/kg	0.3	< 0.30	< 0.30

Compound type	Analytical parameter	Units	Limit of detection	Brember Road Manhole	Newton Park Wetland
PCBs (by MS method)	PCB Congener 28	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 52	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 101	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 118	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 138	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 153	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 180	mg/kg	0.001	< 0.001	< 0.001
Total PCBs (by MS)	PCB Congener 077	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 081	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 105	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 114	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 118	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 123	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 126	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 156	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 157	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 167	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 169	mg/kg	0.001	< 0.001	< 0.001
	PCB Congener 189	mg/kg	0.001	< 0.001	< 0.001