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PFAS in North Carolina

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PFAS in North Carolina

- The scope, extent, and nature of PFAS contamination in North Carolina is the current issue DEQ is working on.
  - Other emerging compounds also being examined, including 1,4,-Dioxane.

- At the last SSAB meeting, DEQ and DHHS heard the perspectives of the Board members for regulation and different strategies that could be applied in NC.

- A summary table was presented, and the Board asked for more information to be added.
  - Expanded toxicity data
  - Environmental data
  - Biological data

Presentation Goals

- This presentation serves as an introduction to the expanded table for both the Board and the public.
- Identify areas of research still needed.
- Provide the Board with potential uses of this data for regulatory purposes and solicit feedback.
- Discuss how to move forward and what the next steps could be.

Most frequently detected PFAS in North Carolina[~]		
PFAS Type	**PFAS Group**	**PFAS Compound**
Legacy Compounds	Sulfonic Acids	PFBS
		PFHxS
		PFOS
	Carboxylic Acids	PFBA
		PFPeA
		PFHxA
		PFOA
		PFNA
		PFDA
Consent Order Compounds		PFHpA
		PFMOPrA[#]
		PFMOBA[#]
	Ether Carboxylic Acids	PFMOAA
		PMPA[#]
		PFO2HxA
		PEPA[#]
		PFO3OA
		HFPO-DA (GenX)
		PFO4DA
		PFO5DA
		HydroEVE
	Ether Sulfonic Acids	Nafion By-prod1
		Nafion By-prod2

- This is a collection of toxicological and environmental data from multiple international and peer-reviewed sources that summarizes the complexity of PFAS data.
  - Both inside and outside of North Carolina.
- The purpose of this data collection is to present the NC Secretaries' Science Advisory Board with a synopsis of data to aid in its support and analysis of PFAS regulatory strategies most appropriate for North Carolina.

~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Most frequently detected PFAS in North Carolina~							
PFAS Type	PFAS Group	PFAS Compound	Physical Characteristics: Fluorinated Carbons	Total Chain Length	Molecular Formula	Molecular Weight (g/mol)	Water Solublity (20-25C (g/L))
Legacy Compounds	Sulfonic Acids	PFBS	4	5	$C_4HF_9O_3S$	300.1	56.6
		PFHxS	6	7	$C_6HF_{13}O_3S$	400.12	2.3
		PFOS	8	9	$C_8HF_{17}O_3S$	500.13	1.57
	Carboxylic Acids	PFBA	3	4	$C_7H_5FO_2$	140.11	0.4
		PFPeA	4	5	C_5HF_9O	264.05	112.6
		PFHxA	5	6	C_6HF_{11}	314.05	21.7
		PFOA	8	8	$C_8HF_{15}O_2$	414.07	9.5
		PFNA	8	9	$C_9HF_{17}O_2$	464.08	9.5
		PFDA	9	10	$C_{10}HF_{19}O_2$	514.08	5.1
Consent Order Compounds		PFHpA	6	7	$C_7HF_{13}O_2$	364.06	4.2
		PFMOPrA#	3	5	$C_4HF_7O_3$	230.04	
		PFMOBA#	4	6	$C_5HF_9O_3$	280.04	
	Ether Carboxylic Acids	PFMOAA	2	4	$C_3HF_5O_3$	180.03	
		PMPA#	3	5	$C_4HF_7O_3$	230.04	
		PFO2HxA	3	6	$C_4HF_7O_4$	246.04	
		PEPA#	4	6	$C_5HF_9O_3$	280.04	
		PFO3OA	4	8	$C_5HF_9O_5$	312.04	
		HFPO-DA (GenX)	5	7	$C_6HF_{11}O_3$	330.05	300
		PFO4DA	5	10	$C_6HF_{11}O_6$	378.05	
		PFO5DA	6	12	$C_7HF_{13}O_7$	444.06	
		HydroEVE	6	10	$C_8H_2F_{14}O_4$	428.08	
	Ether Sulfonic Acids	Nafion By-prod1	7	10	$C_7HF_{13}O_5S$	444.12	
		Nafion By-prod2	7	10	$C_7H_2F_{14}O_5S$	464.13	

Physical Characteristics

- The Physical Characteristics describe the length, weight, and solubility of the PFAS compounds.
- Solubility refers to the number of grams of a substance that can be dissolved in 1 liter of water; the greater the solubility means that more of a substance can be dissolved in water.

~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

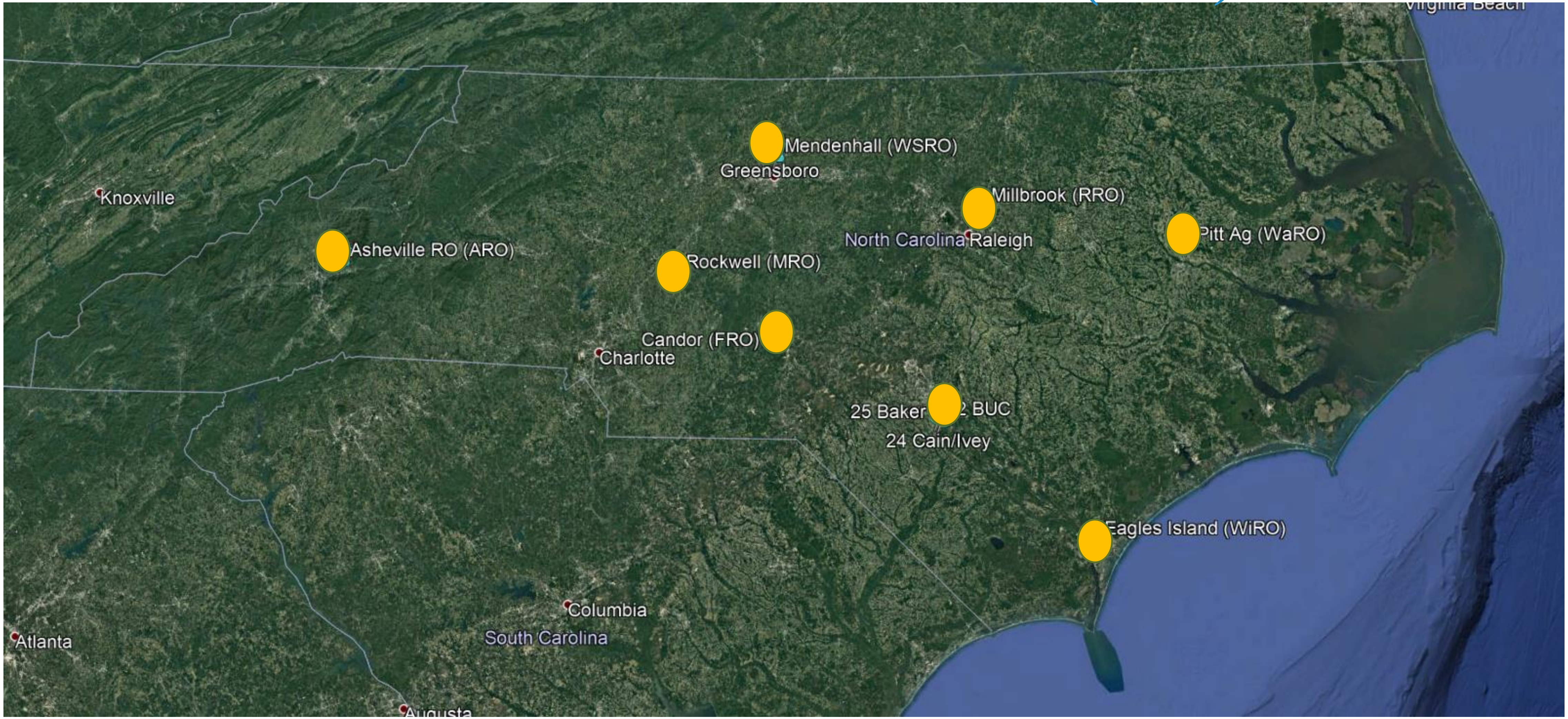
Environmental Data

Most frequently detected PFAS in North Carolina~								
			Environmental Data					
			Concentration in NC water (median (range)) ng/L ppt					
PFAS Type	PFAS Group	PFAS Compound	DAQ Rainwater 2018-2021		Surface water			
			Chemours Area (n = 42)	Regional Sites (n =19)	DWR Lake data (n = 140)	DWR Chemours Outfall 002 (n = 213+)	Cape Fear, Lock & Dam (mean)	Chemours area (mean) (n=100)
Legacy Compounds	Sulfonic Acids	PFBS			40 (37 - -42)	36 (2 - 82)	<10	1.3
		PFHxS	5.9		40 (20 - 70)	37 (2 - 82)	27	0.7
		PFOS	4.2 - 9.7	4.1 - 37	40 (17 - 590)	37 (2 - 82)	29	2.1
	Carboxylic Acids	PFBA	2.0 - 40	4.0 - 8.0	40 (17 - 160)	40 (3 - 160)	31	8.6
		PFPeA	4.3 - 14		40 (17 - 260)	35 (5 - 310)	35	6.3
		PFHxA			40 (31-350)	40 (3 - 98)	33	2
		PFOA	5.4 - 120	5.2 - 7.9	40 (26 - 90)	40 (4 - 130)	21	1
		PFNA			40 (16 - 160)	40 (1 - 82)	<10	0.4
		PFDA			40 (20 - 160)	40 (1 - 200)		3.7
Consent Order Compounds		PFHpA	4.6		40 (13 - 280)	37 (2 - 82)	25	1.3
		PFMOPrA#					@	
		PFMOBA#					@	
	Ether Carboxylic Acids	PFMOAA					95000	76
		PMPA#					740	696.6
		PFO2HxA					8200	296.6
		PEPA#					280	
		PFO3OA					7000	37.2
		HFPO-DA (GenX)			40 (16 - 42)	110 (21 - 39000)+	790	475.2
		PFO4DA					330	5.9
		PFO5DA					153	0.2
		HydroEVE					<10	
	Ether Sulfonic Acids	Nafion By-prod1						
		Nafion By-prod2					<10	18.8

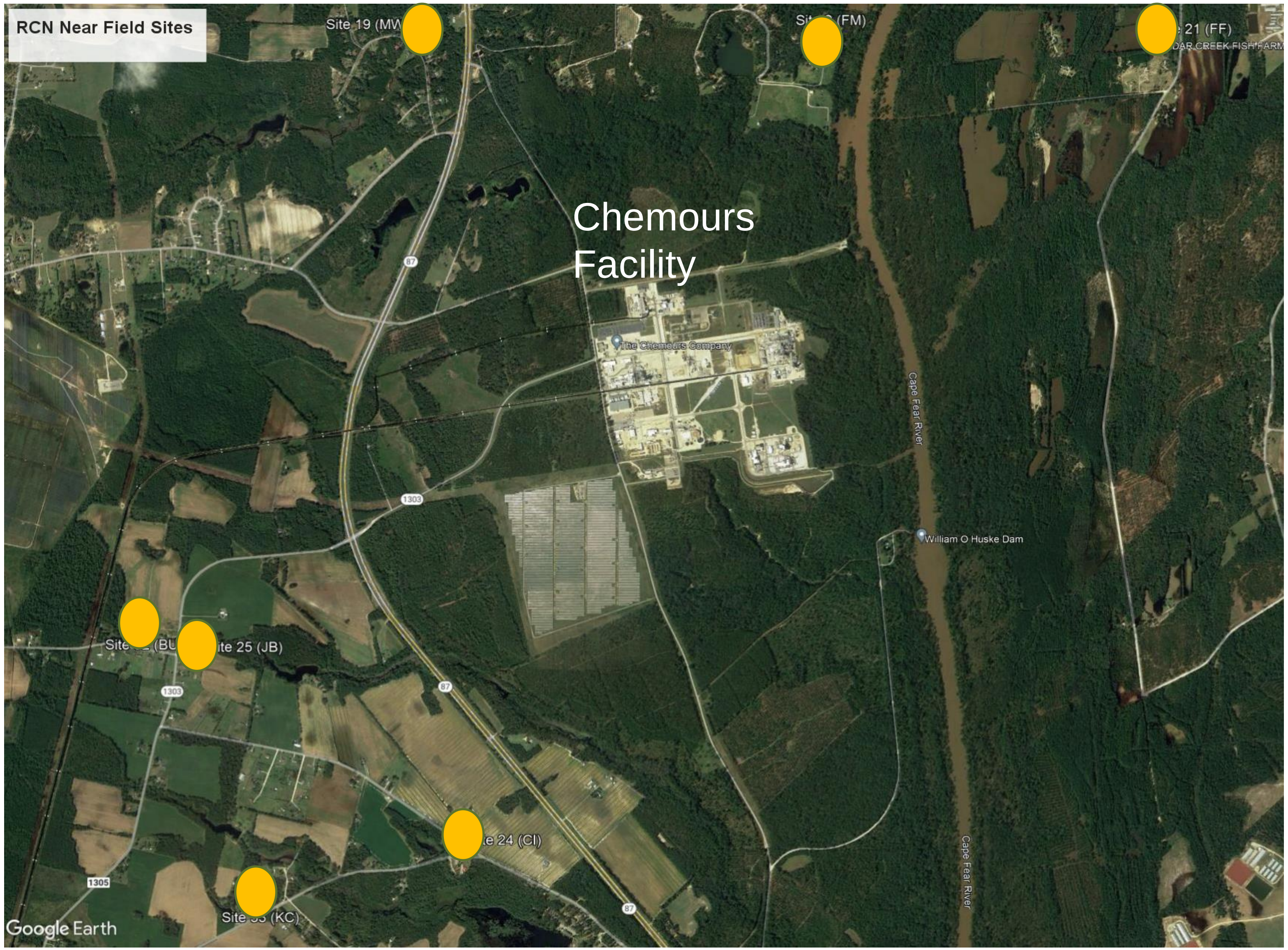
- Rainwater data describes atmospheric deposition of PFAS into rainwater and falling to the ground.
- Surface water is the visible water you can see in streams and lakes.

~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Rainwater Collection Network (RCN)



Rainwater Collection Network Near Field Sites (RCN)



Most frequently detected PFAS in North Carolina~								
			Environmental Persistence Data					
			Concentration in NC water (median (range)) ng/L ppt					
PFAS Type	PFAS Group	PFAS Compound	DAQ Rainwater 2018-2021		Surface water			
			Chemours Area (n = 42)	Regional Sites (n =19)	DWR Chemours Outfall 002 (n = 213+)	Cape Fear, Lock & Dam (mean)	Chemours area (mean) (n=100)	DWR Lake data (n = 140)
Legacy Compounds	Sulfonic Acids	PFBS			36 (2 - 82)	<10	1.3	40 (37 - -42)
Legacy Compounds	Sulfonic Acids	PFHxS	5.9		37 (2 - 82)	27	0.7	40 (20 - 70)
Legacy Compounds	Sulfonic Acids	PFOS	4.2 - 9.7	4.1 - 37	37 (2 - 82)	29	2.1	40 (17 - 590)
Legacy Compounds	Carboxylic Acids	PFBA	2.0 - 40	4.0 - 8.0	40 (3 - 160)	31	8.6	40 (17 - 160)
Legacy Compounds	Carboxylic Acids	PFPeA	4.3 - 14		35 (5 - 310)	35	6.3	40 (17 - 260)
Legacy Compounds	Carboxylic Acids	PFHxA			40 (3 - 98)	33	2	40 (31-350)
Legacy Compounds	Carboxylic Acids	PFOA	5.4 - 120	5.2 - 7.9	40 (4 - 130)	21	1	40 (26 - 90)
Legacy Compounds	Carboxylic Acids	PFNA			40 (1 - 82)	<10	0.4	40 (16 - 160)
Legacy Compounds	Carboxylic Acids	PFDA			40 (1 - 200)		3.7	40 (20 - 160)
Consent Order Compounds	Carboxylic Acids	PFHpA	4.6		37 (2 - 82)	25	1.3	40 (13 - 280)
Consent Order Compounds	Carboxylic Acids	PFMOPrA#				@		
Consent Order Compounds	Carboxylic Acids	PFMOBA#				@		
Consent Order Compounds	Ether Carboxylic Acids	PFMOAA				95000	76	
Consent Order Compounds	Ether Carboxylic Acids	PMPA#				740	696.6	
Consent Order Compounds	Ether Carboxylic Acids	PFO2HxA				8200	296.6	
Consent Order Compounds	Ether Carboxylic Acids	PEPA#				280		
Consent Order Compounds	Ether Carboxylic Acids	PFO3OA				7000	37.2	
Consent Order Compounds	Ether Carboxylic Acids	HFPO-DA (GenX)			110 (21 - 39000)+	790	475.2	40 (16 - 42)
Consent Order Compounds	Ether Carboxylic Acids	PFO4DA				330	5.9	
Consent Order Compounds	Ether Carboxylic Acids	PFO5DA				153	0.2	
Consent Order Compounds	Ether Carboxylic Acids	HydroEVE				<10		
Consent Order Compounds	Ether Sulfonic Acids	Nafion By-prod1						
Consent Order Compounds	Ether Sulfonic Acids	Nafion By-prod2				<10	18.8	

Rainwater Data

- Atmospheric deposition of PFAS into rainwater is not the largest source of PFAS in North Carolina.
  - Small study, limitations
  - Since the Chemours Consent Order required a stack scrubber, 99.9% of PFAS/GenX has been removed from being deposited into the atmosphere.
- Atmospheric Deposition of contaminants is always an important source to consider and will be continually evaluated moving forward.

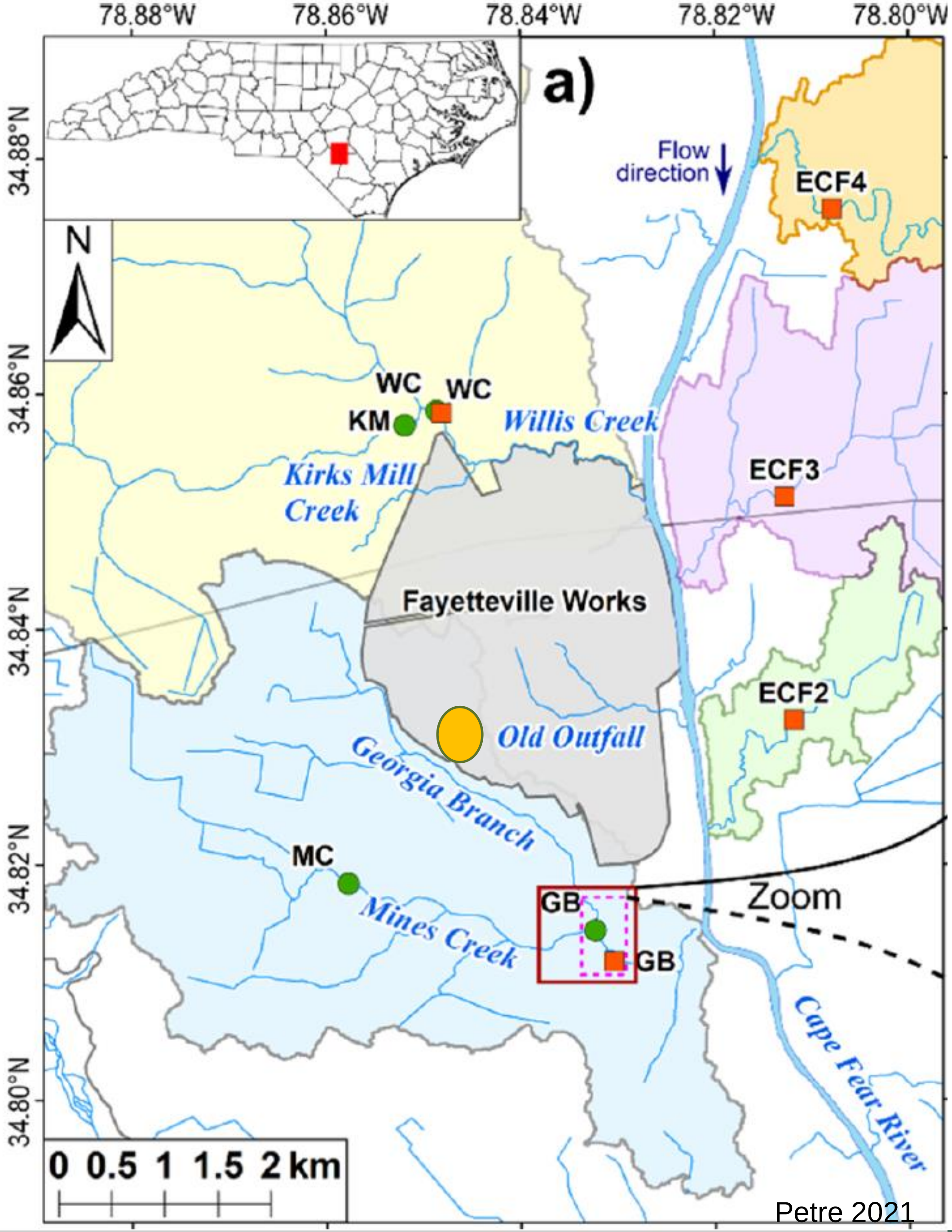
~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Most frequently detected PFAS in North Carolina~								
			Environmental Persistence Data					
			Concentration in NC water (median (range)) ng/L ppt					
			Rainwater 2018-2021		Surface water			
PFAS Type	PFAS Group	PFAS Compound	Chemours Area (n = 42)	Regional Sites (n =19)	DWR Chemours Outfall 002 (n = 213+)	Cape Fear, Lock & Dam (mean)[1]	Chemours area (mean) (n=100)[2]	DWR Lake data (n = 140)
Legacy Compounds	Sulfonic Acids	PFBS			36 (2 - 82)	<10	1.3	40 (37 - -42)
Legacy Compounds	Sulfonic Acids	PFHxS	5.9		37 (2 - 82)	27	0.7	40 (20 - 70)
Legacy Compounds	Sulfonic Acids	PFOS	4.2-9.7	4.1-37	37 (2 - 82)	29	2.1	40 (17 - 590)
Legacy Compounds	Carboxylic Acids	PFBA	2.0-40	4.0-8.0	40 (3 - 160)	31	8.6	40 (17 - 160)
Legacy Compounds	Carboxylic Acids	PFPeA	4.3-14		35 (5 - 310)	35	6.3	40 (17 - 260)
Legacy Compounds	Carboxylic Acids	PFHxA			40 (3 - 98)	33	2	40 (31-350)
Legacy Compounds	Carboxylic Acids	PFOA	5.4- 120	5.2-7.9	40 (4 - 130)	21	1	40 (26 - 90)
Legacy Compounds	Carboxylic Acids	PFNA			40 (1 - 82)	<10	0.4	40 (16 - 160)
Legacy Compounds	Carboxylic Acids	PFDA			40 (1 - 200)		3.7	40 (20 - 160)
Consent Order Compounds	Carboxylic Acids	PFHpA	4.6		37 (2 - 82)	25	1.3	40 (13 - 280)
Consent Order Compounds	Carboxylic Acids	PFMOPrA#				@		
Consent Order Compounds	Carboxylic Acids	PFMOB#				@		
Consent Order Compounds	Ether Carboxylic Acids	PFMOAA				95000	76	
Consent Order Compounds	Ether Carboxylic Acids	PMPA#				740	696.6	
Consent Order Compounds	Ether Carboxylic Acids	PFO2HxA				8200	296.6	
Consent Order Compounds	Ether Carboxylic Acids	PEPA#				280		
Consent Order Compounds	Ether Carboxylic Acids	PFO3OA				7000	37.2	
Consent Order Compounds	Ether Carboxylic Acids	HFPO-DA (GenX)			110 (21 - 39000)+	790	475.2	40 (16 - 42)
Consent Order Compounds	Ether Carboxylic Acids	PFO4DA				330	5.9	
Consent Order Compounds	Ether Carboxylic Acids	PFO5DA				153	0.2	
Consent Order Compounds	Ether Carboxylic Acids	HydroEVE				<10		
Consent Order Compounds	Ether Sulfonic Acids	Nafion By-prod1						
Consent Order Compounds	Ether Sulfonic Acids	Nafion By-prod2				<10	18.8	

Surface Water Data

- Surface water is the visible water you can see in streams and lakes.
- Surface water can collect many sources of contamination and identifying a clear point source can be difficult.
- The data here are from 4 different sources and locations.
- The locations from left to right increase in distance away from the Chemours site.

+- n=234; @- isomers not distinguished in this dataset; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs



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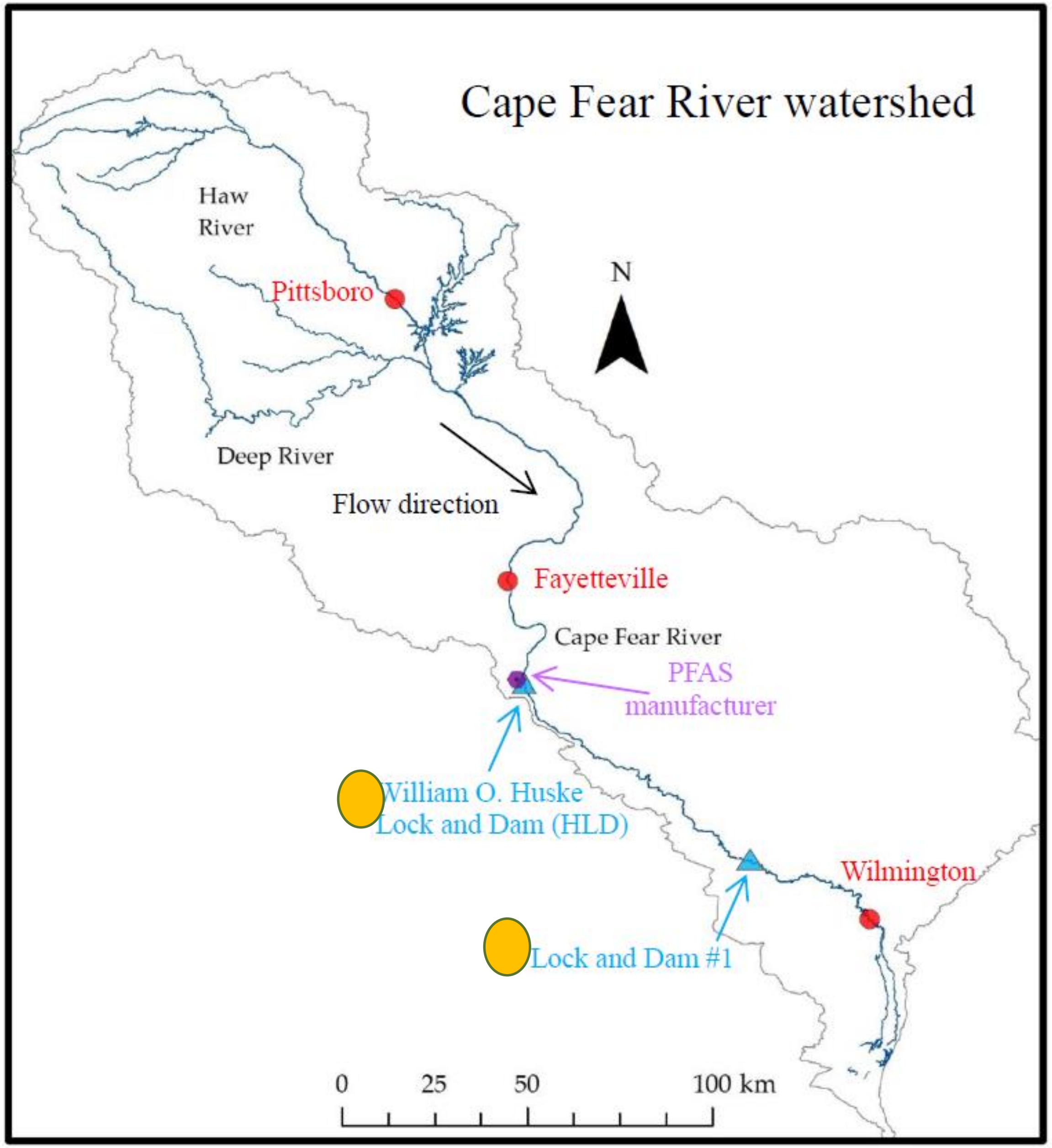
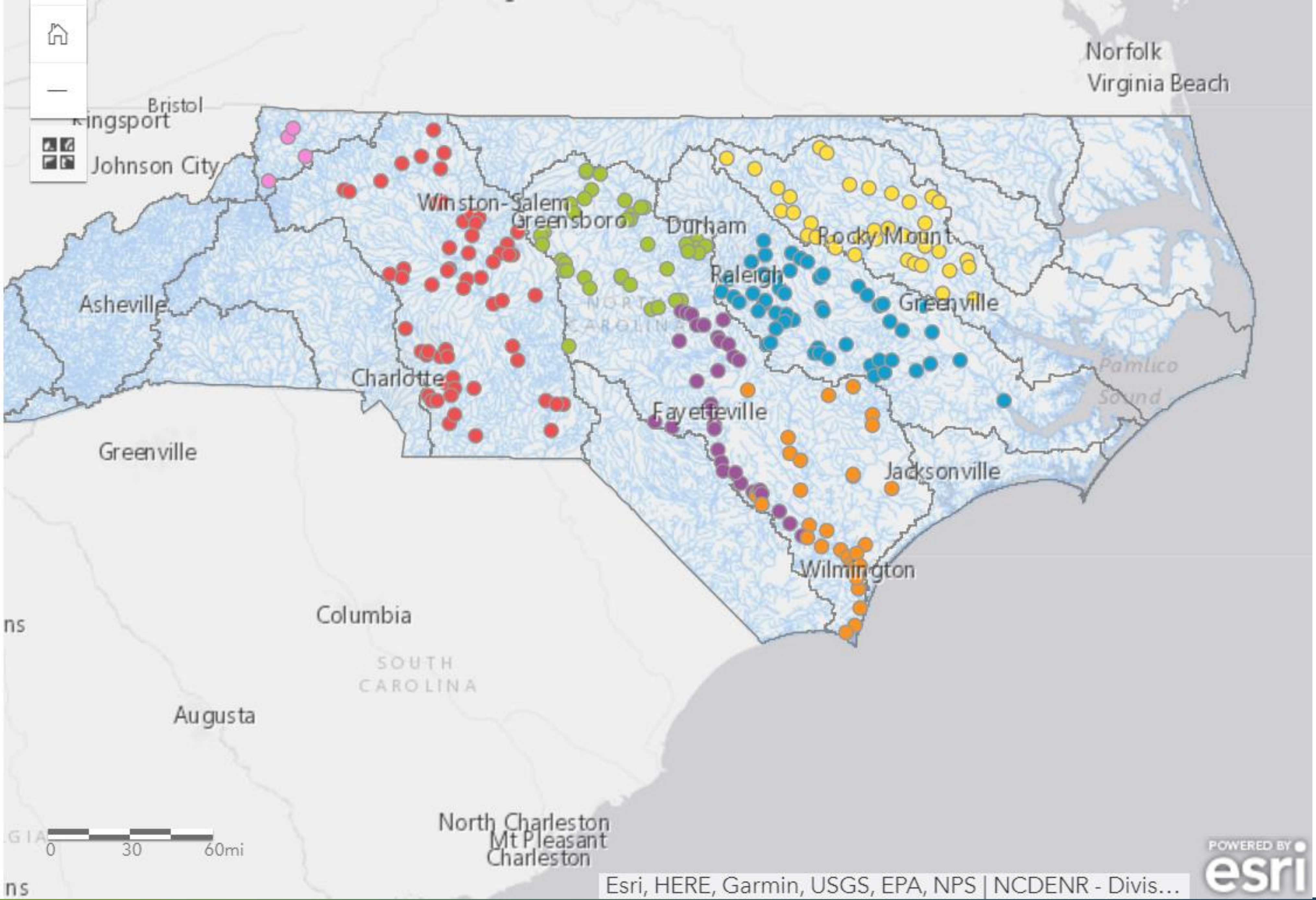


Zhang 2019

DEQ DWR


Norfolk
Virginia Beach
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Johnson City
Winston-Salem
Greensboro
Durham
Rocky Mount
Raleigh
Asheville
Greenville
NORTH CAROLINA
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Jacksonville
Wilmington
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Surface Water Data

Most frequently detected PFAS in North Carolina~

PFAS Type	PFAS Group	PFAS Compound	Environmental Persistence Data – Concentration in NC water (median (range)) ng/L ppt – Rainwater 2018-2021: Chemours Area (n = 42)	Rainwater 2018-2021: Regional Sites (n =19)	Surface water: DWR Chemours Outfall 002 (n = 213+)	Surface water: Cape Fear, Lock & Dam (mean)[1]	Surface water: Chemours area (mean) (n=100)[2]	Surface water: DWR Lake data (n = 140)
Legacy Compounds	Sulfonic Acids	PFBS			36 (2 - 82)	<10	1.3	40 (37 - -42)
		PFHxS	5.9		37 (2 - 82)	27	0.7	40 (20 - 70)
		PFOS	4.2-9.7	4.1-37	37 (2 - 82)	29	2.1	40 (17 - 590)
	Carboxylic Acids	PFBA	2.0-40	4.0-8.0	40 (3 - 160)	31	8.6	40 (17 - 160)
		PFPeA	4.3-14		35 (5 - 310)	35	6.3	40 (17 - 260)
		PFHxA			40 (3 - 98)	33	2	40 (31-350)
		PFOA	5.4- 120	5.2-7.9	40 (4 - 130)	21	1	40 (26 - 90)
		PFNA			40 (1 - 82)	<10	0.4	40 (16 - 160)
		PFDA			40 (1 - 200)		3.7	40 (20 - 160)
Consent Order Compounds		PFHpA	4.6		37 (2 - 82)	25	1.3	40 (13 - 280)
		PFMOPrA#				@		
		PFMOBA#				@		
	Ether Carboxylic Acids	PFMOAA				95000	76	
		PMPA#				740	696.6	
		PFO2HxA				8200	296.6	
		PEPA#				280		
		PFO3OA				7000	37.2	
		HFPO-DA (GenX)			110 (21 - 39000)+	790	475.2	40 (16 - 42)
		PFO4DA				330	5.9	
		PFO5DA				153	0.2	
		HydroEVE				<10		
	Ether Sulfonic Acids	Nafion By-prod1						
		Nafion By-prod2				<10	18.8	

- Surface water values can be confused by the presence/absence of point sources of contamination.
- Moving away from a point source can show a gradient of values.
- The lake data is pooled from all 270 sampling sites across the State of NC, including those downstream of a known point source.

+- n=234; @- isomers not distinguished in this dataset; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Most frequently detected PFAS in North Carolina~

PFAS Type	PFAS Group	PFAS Compound	Environmental Data: Concentration in NC water (median (range)) ng/L ppt — Drinking Water Wells/ Groundwater: Chemours area (n=3406)	% Detection (n)
Legacy Compounds	Sulfonic Acids	PFBS	2.9 (0.9 - 21)	1.8% (63)
		PFHxS	3.5 (1.9 - 11)	1% (37)
		PFOS	6.9 (2.2 - 39)	1.4% (49)
	Carboxylic Acids	PFBA	7.5 (2.2 - 300)	3.2% (109)
		PFPeA	6.8 (2 - 53)	3.2% (109)
		PFHxA	3.4 (1.9 - 29)	2.5% (85)
		PFOA	4.5 (1.1 -61)	2.6% (89)
		PFNA	3.5 (2.3 - 7.5)	0.2% (8)
		PFDA	3.2 (3 - 7.5)	0.1% (3)
Consent Order Compounds		PFHpA	3 (0.9 - 43)	22% (740)
		PFMOPrA#	@	@
		PFMOBA#	@	@
	Ether Carboxylic Acids	PFMOAA	13 (2 - 3500)	66% (2241)
		PMPA#	63 (2 - 8800)	92% (3117)
		PFO2HxA	13 (1.5 - 2800)	73% (2495)
		PEPA#	33 (2 - 2100)	23% (792)
		PFO3OA	4.6 (1.3 - 490)	21% (704)
		HFPO-DA (GenX)	15 (2 - 3200)	69% (2355)
		PFO4DA	3.5 (1.1 - 230)	6% (216)
		PFO5DA	5.1 (2.1 - 460)	1% (34)
		HydroEVE		
	Ether Sulfonic Acids	Nafion By-prod1	4.6 (1.5 - 20)	0.4% (14)
		Nafion By-prod2	5.5 (1.1 - 110)	51% (1748)

Groundwater Data

- Drinking water wells that are sourced through ground water have different PFAS concentrations.
- All values are median values- across individual wells and across the entire dataset.
  - Unique measurements may have had greater/lesser concentrations in previous DEQ presentations.
  - The median was calculated to be consistent across the entire table.
- Consent order compounds are most relevant to this area

@- isomers not distinguished in this dataset; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Groundwater Data

Most frequently detected PFAS in North Carolina~

PFAS Type	PFAS Group	PFAS Compound	Environmental Data — Concentration in NC water (median (range)) ng/L — Drinking Water Wells/ Groundwater: Chemours area (n=3406)	% Detection (n)	States with Regulation or Guidance ?
Legacy Compounds	Sulfonic Acids	PFBS	2.9 (0.9 - 21)	1.8% (63)	MI, MN
		PFHxS	3.5 (1.9 - 11)	1% (37)	VT, RI, MA, NH, MN,CT, AK, CO, DE, ME, MI, NM[3]
		PFOS	6.9 (2.2 - 39)	1.4% (49)	MN, NH, RI, CA, NJ, NY
	Carboxylic Acids	PFBA	7.5 (2.2 - 300)	3.2% (109)	MN
		PFPeA	6.8 (2 - 53)	3.2% (109)	None
		PFHxA	3.4 (1.9 - 29)	2.5% (85)	MI
		PFOA	4.5 (1.1 -61)	2.6% (89)	CA, RI, MA, NH, NY, CT, ME, AK, CO, DE, NM
		PFNA	3.5 (2.3 - 7.5)	0.2% (8)	MA, CT, NJ, NH, RI,
		PFDA	3.2 (3 - 7.5)	0.1% (3)	MA
Consent Order Compounds		PFHpA	3 (0.9 - 43)	22% (740)	VT, CT , MA, RI
		PFMOPrA#	@	@	None
		PFMOBA#	@	@	None
	Ether Carboxylic Acids	PFMOAA	13 (2 - 3500)	66% (2241)	None
		PMPA#	63 (2 - 8800)	92% (3117)	None
		PFO2HxA	13 (1.5 - 2800)	73% (2495)	None
		PEPA#	33 (2 - 2100)	23% (792)	None
		PFO3OA	4.6 (1.3 - 490)	21% (704)	None
		HFPO-DA (GenX)	15 (2 - 3200)	69% (2355)	NC, MI, OH
		PFO4DA	3.5 (1.1 - 230)	6% (216)	None
		PFO5DA	5.1 (2.1 - 460)	1% (34)	None
		HydroEVE			None
	Ether Sulfonic Acids	Nafion By-prod1	4.6 (1.5 - 20)	0.4% (14)	None
		Nafion By-prod2	5.5 (1.1 - 110)	51% (1748)	None

- Consent order compounds are most relevant to this area.
- The Consent Order group of PFAS have less data than the legacy group.
- Not yet regulated by any state.
- GenX has health advisories in 3 states.

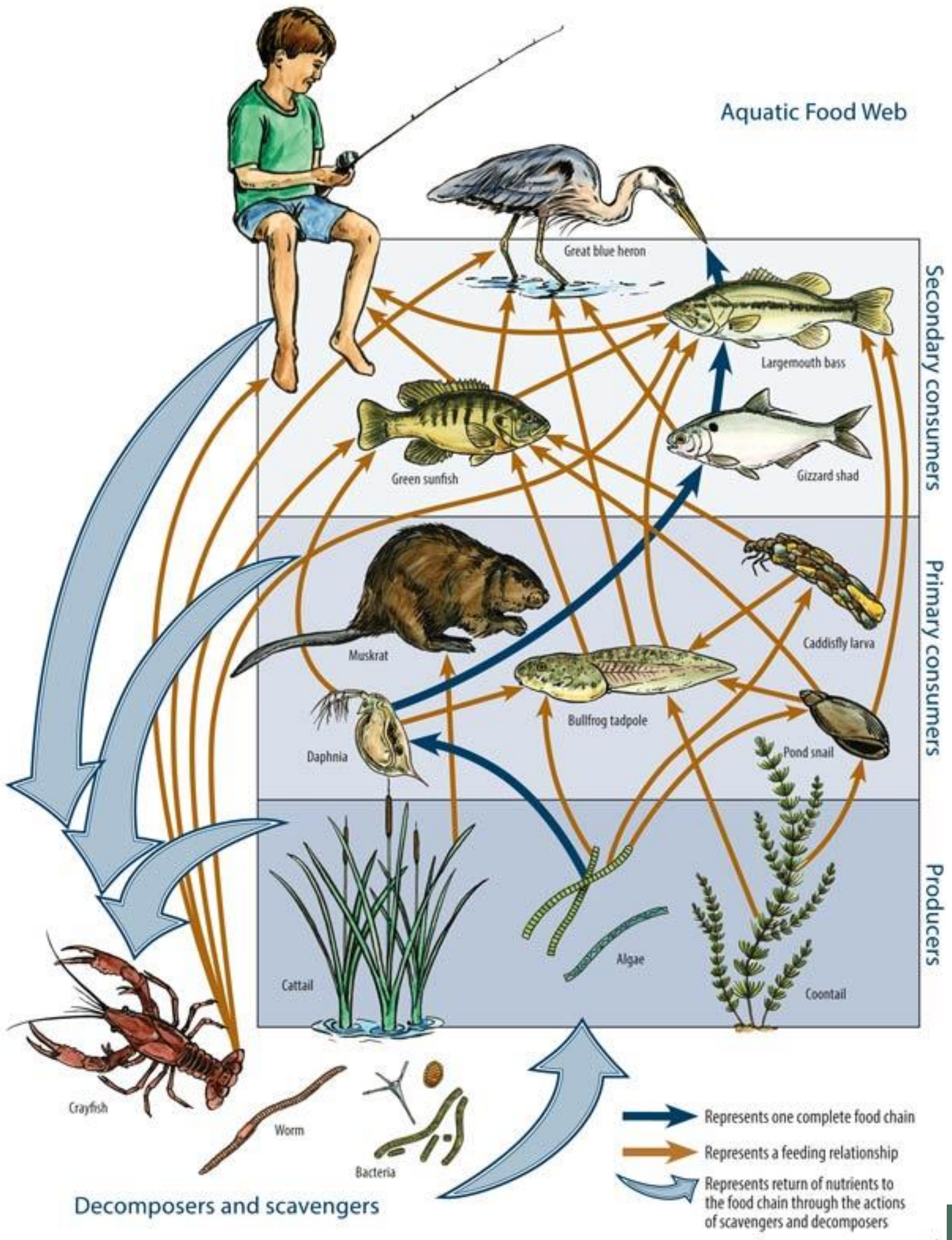
@- isomers not distinguished in this dataset; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Blood Serum Data

Most frequently detected PFAS in North Carolina~						
			Biological Data			
			Conc in NC Striped Bass Serum [mean (range)] ng/L parts per trillion[4]			
PFAS Type	PFAS Group	PFAS Compound	Pamlico Field Lab (n = 29)	% Detection	Cape Fear River (n= 58)	% Detection
Legacy Compounds	Sulfonic Acids	PFBS	10 (10 - 200)	45%	200 (10 - 1400)	24%
		PFHxS	600	3%	800 (200 - 1000)	98%
		PFOS	9400 (4600 - 16500)	100%	490000 (122000 - 977000)	100%
	Carboxylic Acids	PFBA	all < LOD	0%	100 (100 - 200)	14%
		PFPeA				
		PFHxA				
		PFOA	200 (200 - 1100)	14%	600 (200 - 4300)	15%
		PFNA	500 (300 - 800)	96%	4500 (800 - 11600)	100%
		PFDA	2500 (1700 - 4600)	96%	68000 (10200 - 146000)	100%
Consent Order Compounds		PFHpA				
		PFMOPrA#				
		PFMOBA#				
	Ether Carboxylic Acids	PFMOAA				
		PMPA#	100 (100 -100)	10%	100 (100 - 200)	14%
		PFO2HxA				
		PEPA#				
		PFO3OA				
		HFPO-DA (GenX)	160 (200 - 230)	10%	1900 (300 - 5900)	48%
		PFO4DA				
		PFO5DA	all < LOD	0%	500 (10 - 1400)	22%
		HydroEVE				
	Ether Sulfonic Acids	Nafion By-prod1				
		Nafion By-prod2	all < LOD	0%	300 (300-1000)	78%

- Blood data values are generally greater than water values since it is a biological fluid and is reflective of bioaccumulation.
- This data tells us that a higher trophic level fish is accumulating PFAS in greater concentrations than is in the water in which it lives.
  - Suggests bioaccumulation, not necessarily biomagnification.
- This data suggests that fish that are consumed by humans are accumulating PFAS and are a source of exposure.
- More data is needed.

@- isomers not distinguished in this dataset; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs



- To better understand human exposure from fish consumption, more data is needed about contamination through the food web to determine if biomagnification is occurring.
  - 10x increase in concentration with each trophic level
- The muscle of fish needs to be examined to determine how much of the PFAS is portioning into that tissue.
  - This is the best metric of human exposure.
  - This has not been done yet.

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Most frequently detected PFAS in North Carolina~									
			Biological Data						
			Blood Serum Data [median (range)] ng/L parts per trillion						
PFAS Type	PFAS Group	PFAS Compound	Wilmington NC[5]				Pittsboro NC[6]	Fayetteville Works adjacent, NC[7]	NHANES Data US Population [geo mean (95%CI)] (n=1929)[8]
			Adults (n=289)	% Detection (n)	Children (n=55)	% Detection (n)	Adults (n=49)	Aduts (n=30)	
Legacy Compounds	Sulfonic Acids	PFBS							
		PFHxS	3500 (1200 - 8600)	98% (282)	1900 (1.2-4.7)	98% (54)	3000 (20 - 12500)	2100 (700 - 6700)	1080 (990 - 1180)
		PFOS	9400 (3800-28200)	99% (287)	5100 (2800-11500)	100% (55)	11600 (3200 - 31800)	5500 (1400 - 34600)	4250 (3900 - 4620)
	Carboxylic Acids	PFBA							
		PFPeA							
		PFHxA					1500 (300 - 4000)		<LOD
		PFOA	4800 (1700 - 11300)	99.7% (288)	3000 (1900 - 6500)	100% (*55)	6400 (2100 - 42400)	1800 (400 - 7300)	1420 (1330 - 1520)
		PFNA	1300 (600 - 3600)	97% (280)	800 (400 - 1500)	82% (45)	1500 (300 - 9500)	600 (<100 - 2100)	411 (360 - 460)
		PFDA					600 (400 - 2400)	200 (<100 - 1300)	200 (180 - 210)
Consent Order Compounds		PFHpA	200 (100 - 1400)	59% (170)	400 (200 - 1000)	98% (54)		100 (<100 - 600)	
		PFMOPrA#							
		PFMOBA#							
	Ether Carboxylic Acids	PFMOAA							
		PMPA#							
		PFO2HxA							
		PEPA#							
		PFO3OA							
		HFPO-DA (GenX)	not detected	0%	not detected	0%	not detected	not detected	<LOD
		PFO4DA	2300 (400 - 13700)	98% (284)	2600 (700 - 8900)	100% (55)			
		PFO5DA	300 (100 - 1000)	89% (256)	200 (100 - 400)	84% (46)			
		HydroEVE							
	Ether Sulfonic Acids	Nafion By-prod1							
		Nafion By-prod2	3200 (1000 - 8500)	99% (286)	1600 (600 - 3800)	100% (55)			

~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Blood Serum Data

- Blood data values are generally greater than water values since it is a biological fluid and is reflective of bioaccumulation.
- Human blood data can tell us more about the exposure and accumulation that is occurring in North Carolina compared to the rest of the Unites States.

Most frequently detected PFAS in North Carolina~

PFAS Type	PFAS Group	PFAS Compound	Toxicity Data: Cellular Receptor Activity (mean fold induction relative to control)				
			PPARα[9]	PPARγ[9]	RXRβ[9]	ERα[9]	Other Active Sites[10]
Legacy Compounds	Sulfonic Acids	PFBS	1 - 5	1.5 - 11	1 - 1.5	0.5 - 5	CYP3A4, CYP2D6, CNG, ALDH1A1, NPSR, HTTQ103, VP16,RORγ, G9a, JMJD2A, Nrf2, ELG1, Smad3, Gsgap, DNA re-replication, GLP-1, ATXN, HT-1080-NT, DT40-hTDP1, Plk PBD
		PFHxS					
		PFOS					
	Carboxylic Acids	PFBA	1 - 12 PFOA =15	1 - 21 PFOA = 22	1 - 18 PFOA = 13	1 - 9 PFOA = 7	
		PFPeA					
		PFHxA					
		PFOA					
		PFNA					
		PFDA					
Consent Order Compounds		PFHpA					
		PFMOPrA#					
		PFMOBA#					
	Ether Carboxylic Acids	PFMOAA	3 - 7	5.5 - 9	1.5 - 11	1 - 2	CYP2D6, HTTQ103, G9a, JMJD2A, ATXN, HT-1080-NT, DT40-hTDP1
		PMPA#					
		PFO2HxA					
		PEPA#					
		PFO3OA					
		HFPO-DA (GenX)					
		PFO4DA					
		PFO5DA					
		HydroEVE					
	Ether Sulfonic Acids	Nafion By-prod1					
		Nafion By-prod2					

Toxicity Data

- Toxicity data tells us what PFAS does biochemically in the body.
- Cellular receptors are sites on the cells that can interact with proteins and contaminants.

- PPARα reduces triglyceride level and is involved in regulation of energy homeostasis.
- PPARγ causes insulin sensitization and enhances glucose metabolism.
- RXRβ mediates the effects of retinoic acid which is related to learning and memory.
- ERα1 is activated by the sex hormone estrogen.

Receptor data based on ToxPrint groups, see Table S1; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

<table>
<tr><th colspan="8">Most frequently detected PFAS in North Carolina~</th></tr>
<tr><th rowspan="3">PFAS Type</th><th rowspan="3">PFAS Group</th><th rowspan="3">PFAS Compound</th><th colspan="5">Toxicity Data</th></tr>
<tr><th colspan="5">Cellular Receptor Activity
(mean fold induction relative to control)</th></tr>
<tr><th>PPARα[9]</th><th>PPARγ[9]</th><th>RXRβ[9]</th><th>ERα[9]</th><th>Other Active Sites[10]</th></tr>
<tr><td rowspan="9">Legacy Compounds</td><td rowspan="3">Sulfonic Acids</td><td>PFBS</td><td rowspan="3">1 - 5</td><td rowspan="3">1.5 - 11</td><td rowspan="3">1 - 1.5</td><td rowspan="3">0.5 - 5</td><td rowspan="12">CYP3A4, CYP2D6, CNG, ALDH1A1, NPSR, HTTQ103, VP16,RORγ, G9a, JMJD2A, Nrf2, ELG1, Smad3, Gsgap, DNA re-replication, GLP-1, ATXN, HT-1080-NT, DT40-hTDP1, Plk PBD</td></tr>
<tr><td>PFHxS</td></tr>
<tr><td>PFOS</td></tr>
<tr><td rowspan="9">Carboxylic Acids</td><td>PFBA</td><td rowspan="7">1 - 12
PFOA =15</td><td rowspan="7">1 - 21
PFOA = 22</td><td rowspan="7">1 - 18
PFOA = 13</td><td rowspan="7">1 - 9
PFOA = 7</td></tr>
<tr><td>PFPeA</td></tr>
<tr><td>PFHxA</td></tr>
<tr><td>PFOA</td></tr>
<tr><td>PFNA</td></tr>
<tr><td>PFDA</td></tr>
<tr><td rowspan="14">Consent Order Compounds</td><td>PFHpA</td></tr>
<tr><td>PFMOPrA#</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>PFMOBA#</td></tr>
<tr><td rowspan="9">Ether Carboxylic Acids</td><td>PFMOAA</td><td rowspan="9">3 - 7</td><td rowspan="9">5.5 - 9</td><td rowspan="9">1.5 - 11</td><td rowspan="9">1 - 2</td><td rowspan="11">CYP2D6, HTTQ103, G9a, JMJD2A, ATXN, HT-1080-NT, DT40-hTDP1</td></tr>
<tr><td>PMPA#</td></tr>
<tr><td>PFO2HxA</td></tr>
<tr><td>PEPA#</td></tr>
<tr><td>PFO3OA</td></tr>
<tr><td>HFPO-DA (GenX)</td></tr>
<tr><td>PFO4DA</td></tr>
<tr><td>PFO5DA</td></tr>
<tr><td>HydroEVE</td></tr>
<tr><td rowspan="2">Ether Sulfonic Acids</td><td>Nafion By-prod1</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Nafion By-prod2</td></tr>
</table>

Toxicity Data

- The numbers indicate the ‘average fold induction’ above a control chemical.
- This number shows how much greater the PFAS interacted with the cellular receptors than the control chemical.
- This helps us understand how PFAS acts in the body and possible health effects.

~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Most frequently detected PFAS in North Carolina~			Toxicity Data		
PFAS Type	PFAS Group	PFAS Compound	Non- Mammalian	Mammalian	Relative Potency in Rat (as compared to PFOA)
Legacy Compounds	Sulfonic Acids	PFBS	Zebrafish, Medaka, Trout[11-13]	Rat[26]	0.001
		PFHxS	Zebrafish[14,15]	Mouse[21]	0.6
		PFOS	Zebrafish, Daphnia, Mysid Shrimp, Trout[14-16]	Rat[26,27]	2
	Carboxylic Acids	PFBA	Daphnia, Zebrafish, Trout[17-19]	Rat[26]	0.05
		PFPeA	Daphnia, Trout[17-18]	Rat, Mouse[26,28]	0.01<RPF<0.05
		PFHxA	Zebrafish, Daphnia, Trout [15,17-19]	Rat, Mouse[26,28]	0.01
		PFOA	Zebrafish, Minnow, Daphnia[14-18]	Rat, Mouse[26,28,29]	***1***
		PFNA	Daphnia [20,21]	Mouse[34]	10
		PFDA	Daphnia, Trout[21]	Rat[26]	0.01<RPF<10
Consent Order Compounds		PFHpA	Zebrafish, Daphnia[14,21]	Mouse[28]	0.01<RPF<1
		PFMOPrA#		Mouse[30]	
		PFMOBA#	Zebrafish[22]	Mouse[30]	
	Ether Carboxylic Acids	PFMOAA	Zebrafish[22]	Mouse[30,31]	~1[22,35]
		PMPA#	Zebrafish[22]		~1[22,35]
		PFO2HxA	Zebrafish[22]		~1[22,35]
		PEPA#	Zebrafish[22]		~1[22,35]
		PFO3OA	Zebrafish[22,23]		~1[22,35]
		HFPO-DA (GenX)	Zebrafish[22,24,25]*	Rat, Mouse[26,29,32]	~1[22,35]
		PFO4DA	Zebrafish[22,23]	*[24,25]	~1[22,35]
		PFO5DA	Zebrafish[22,24,25]*	*[24,25]	~1[22,35]
		HydroEVE	Zebrafish[22,24,25]*	*[24,25]	~1[22,35]
	Ether Sulfonic Acids	Nafion By-prod1			
		Nafion By-prod2	*[24,25]	Mouse[33]	

Toxicity Data

- After cellular effects, toxicology moves to animal science.
- There are both mammalian and non-mammalian model animals used in the laboratory.
  - All offer different advantages depending on the question the researcher is asking, and no single model animal is better or more appropriate than others.

*= forthcoming reviews[24,25]; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Most frequently detected PFAS in North Carolina~

PFAS Type	PFAS Group	PFAS Compound	Toxicity Data		
			Non- Mammalian	Mammalian	Relative Potency in Rat (as compared to PFOA)
Legacy Compounds	Sulfonic Acids	PFBS	Zebrafish, Medaka, Trout[11-13]	Rat[26]	0.001
		PFHxS	Zebrafish[14,15]	Mouse[21]	0.6
		PFOS	Zebrafish, Daphnia, Mysid Shrimp, Trout[14-16]	Rat[26,27]	2
	Carboxylic Acids	PFBA	Daphnia, Zebrafish, Trout[17-19]	Rat[26]	0.05
		PFPeA	Daphnia, Trout[17-18]	Rat, Mouse[26,28]	0.01<RPF<0.05
		PFHxA	Zebrafish, Daphnia, Trout [15,17-19]	Rat, Mouse[26,28]	0.01
		PFOA	Zebrafish, Minnow, Daphnia[14-18]	Rat, Mouse[26,28,29]	*1*
		PFNA	Daphnia [20,21]	Mouse[34]	10
		PFDA	Daphnia, Trout[21]	Rat[26]	0.01<RPF<10
Consent Order Compounds		PFHpA	Zebrafish, Daphnia[14,21]	Mouse[28]	0.01<RPF<1
		PFMOPrA#		Mouse[30]	
		PFMOBA#	Zebrafish[22]	Mouse[30]	
	Ether Carboxylic Acids	PFMOAA	Zebrafish[22]	Mouse[30,31]	~1[22,35]
		PMPA#	Zebrafish[22]		~1[22,35]
		PFO2HxA	Zebrafish[22]		~1[22,35]
		PEPA#	Zebrafish[22]		~1[22,35]
		PFO3OA	Zebrafish[22,23]		~1[22,35]
		HFPO-DA (GenX)	Zebrafish[22,24,25]*	Rat, Mouse[26,29,32]	~1[22,35]
		PFO4DA	Zebrafish[22,23]	*[24,25]	~1[22,35]
		PFO5DA	Zebrafish[22,24,25]*	*[24,25]	~1[22,35]
		HydroEVE	Zebrafish[22,24,25]*	*[24,25]	~1[22,35]
	Ether Sulfonic Acids	Nafion By-prod1			
		Nafion By-prod2	*[24,25]	Mouse[33]	

*= forthcoming reviews[24,25]; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

Most frequently detected PFAS in North Carolina~

PFAS Type	PFAS Group	PFAS Compound	Toxicity Data: Non- Mammalian	Toxicity Data: Mammalian	Toxicity Data: Relative Potency in Rat (as compared to PFOA)
Legacy Compounds	Sulfonic Acids	PFBS	Zebrafish, Medaka, Trout[11-13]	Rat[26]	0.001[36]
		PFHxS	Zebrafish[14,15]	Mouse[21]	0.6[36]
		PFOS	Zebrafish, Daphnia, Mysid Shrimp, Trout[14-16]	Rat[26,27]	2[36]
	Carboxylic Acids	PFBA	Daphnia, Zebrafish, Trout[17-19]	Rat[26]	0.05[36]
		PFPeA	Daphnia, Trout[17-18]	Rat, Mouse[26,28]	0.01<RPF<0.05[36]
		PFHxA	Zebrafish, Daphnia, Trout [15,17-19]	Rat, Mouse[26,28]	0.01[36]
		PFOA	Zebrafish, Minnow, Daphnia[14-18]	Rat, Mouse[26,28,29]	***1***[36]
		PFNA	Daphnia [20,21]	Mouse[34]	10[36]
		PFDA	Daphnia, Trout[21]	Rat[26]	0.01<RPF<10[36]
Consent Order Compounds		PFHpA	Zebrafish, Daphnia[14,21]	Mouse[28]	0.01<RPF<1[36]
		PFMOPrA#		Mouse[30]	
		PFMOBA#	Zebrafish[22]	Mouse[30]	
	Ether Carboxylic Acids	PFMOAA	Zebrafish[22]	Mouse[30,31]	~1[22,35]
		PMPA#	Zebrafish[22]		~1[22,35]
		PFO2HxA	Zebrafish[22]		~1[22,35]
		PEPA#	Zebrafish[22]		~1[22,35]
		PFO3OA	Zebrafish[22,23]		~1[22,35]
		HFPO-DA (GenX)	Zebrafish[22,24,25]*	Rat, Mouse[26,29,32]	~1[22,35]
		PFO4DA	Zebrafish[22,23]	*[24,25]	~1[22,35]
		PFO5DA	Zebrafish[22,24,25]*	*[24,25]	~1[22,35]
		HydroEVE	Zebrafish[22,24,25]*	*[24,25]	~1[22,35]
	Ether Sulfonic Acids	Nafion By-prod1			
		Nafion By-prod2	*[24,25]	Mouse[33]	

Toxicity Data

- Relative Potency is an estimate of the adverse effects based on a chemical that we know more about.
- In this data, PFOA is the chemical all others are compared to and takes a value of 1.
- The effects of the other PFAS are compared to PFOA so all other numbers are relative to 1.

*= forthcoming reviews[24,25]; ~- based on Dec 7, 2020, SSAB meeting presentations; # - branched and linear isomer pairs

How can we use all this data?

- The data provides a lot of information – how can we use it?
  - Other states have not regulated some of the most prevalent PFAS in NC.
  - One exception – PFHpA;
    - This is a Consent Order compound that is regulated in other states, less potent and prevalent than some others.
    - It has a 22% detection in groundwater and has been detected in human samples.
    - Found in lakes across NC and in rainwater close to the Chemours site.

  - Recent development in sampling and analysis of PFAS foam throughout the state is providing more information about the complexity of PFAS contamination.

How can we use all this data?

- Potential Options:
  1. Determine which PFAS are at the nexus of having the most information and being the most prevalent in NC and start with that group.
     1. Use PFHpA as a starting point and build on similar characteristics and data?
  2. Emulate the regulations of other states that have grouped legacy PFAS.
  3. Work only with those that are the most prevalent in NC regardless of the amount of information that is known about them.
  4. How to proceed with PFAS either as class or individually?
     1. Current Congressional and EPA activities could influence our path forward.

How could we use PFHpA as a starting point?

PFAS Group	PFAS Compound	Fluorinated Carbons	Total Chain Length	Molecular Formula	Molecular Weight (g/mol)	Water Solublity (20-25C (g/L))	PPARα[1]	PPARγ[1]	RXRβ[1]	ERα[1]	Other Active Sites[20]	Non- Mammalian	Mammalian	Relative Potency in Rat (as compared to PFOA)	Surface water				Drinking Water Wells/ Groundwater		Pamlico Field Lab (n = 29)	% Detection	Cape Fear River (n= 58)	% Detection	Adults (n=289)	% Detection (n)	Children (n=55)	% Detection (n)	Aduts (n=30)	States with Regulation or Guidance ?
Carboxylic Acids	PFHpA	6	7	$C_7HF_{13}O_2$	364.06	4.2	1 - 12	1 - 21	1 - 18	1 - 9	Many	Zebrafish, Daphnia	Mouse	0.01<RPF<1	37 (2 - 82)	25	1.3	40 (13 - 280)	3 (0.9 - 43)	22% (740)					200 (100 - 1400)	59% (170)	400 (200 - 1000)	98% (54)	100 (<100 - 600)	VT, CT , MA, RI
Ether Carboxylic Acids	PFMOAA	2	4	$C_3HF_5O_3$	180.03		3 - 7	5.5 - 9	1.5 - 11	1 - 2	CYP2D6, HTTQ103, G9a, JMJD2A, ATXN, HT-1080-NT, DT40-hTDP1	Zebrafish	Mouse	~1		95000	76		13 (2 - 3500)	66% (2241)										
	PMPA#	3	5	$C_4HF_7O_3$	230.04							Zebrafish		~1		740	696.6		63 (2 - 8800)	92% (3117)	100 (100 - 100)	10%	100 (100 - 200)	14%						
	PFO2HxA	3	6	$C_4HF_7O_4$	246.04							Zebrafish		~1		8200	296.6		13 (1.5 - 2800)	73% (2495)										
	PEPA#	4	6	$C_5HF_9O_3$	280.04							Zebrafish		~1		280			33 (2 - 2100)	23% (792)										
	PFO3OA	4	8	$C_5HF_9O_5$	312.04							Zebrafish		~1		7000	37.2		4.6 (1.3 - 490)	21% (704)										
	HFPO-DA (GenX)	5	7	$C_6HF_{11}O_3$	330.05	300						Zebrafish*	Rat, Mouse [5,14,19]	~1	110 (21 - 39000)+	790	475.2	40 (16 - 42)	15 (2 - 3200)	69% (2355)	160 (200 - 230)	10%	1900 (300 - 5900)	48%						
	PFO4DA	5	10	$C_6HF_{11}O_6$	378.05							Zebrafish	*	~1		330	5.9		3.5 (1.1 - 230)	6% (216)					2300 (400 - 13700)	98% (284)	2600 (700 - 8900)	100% (55)		
	PFO5DA	6	12	$C_7HF_{13}O_7$	444.06							Zebrafish*	*	~1^		153	0.2		5.1 (2.1 - 460)	1% (34)	all < LOD	0%	500 (10 - 1400)	22%	300 (100 - 1000)	89% (256)	200 (100 - 400)	84% (46)		
	HydroEVE	6	10	$C_8H_2F_{14}O_4$	428.08							Zebrafish*	*	~1		<10														
Ether Sulfonic Acids	Nafion By-prod1	7	10	$C_7HF_{13}O_5S$	444.12														4.6 (1.5 - 20)	0.4% (14)										
	Nafion By-prod2	7	10	$C_7H_2F_{14}O_5S$	464.13							*	Mouse[23]			<10	18.8		5.5 (1.1 - 110)	51% (1748)	all < LOD	0%	300 (300-1000)	78%	3200 (1000 - 8500)	99% (286)	1600 (600 - 3800)	100% (55)		

Department of Environmental Quality

Questions for the Board

- Does the expanded data table change or strengthen the recommendations you made at the last meeting?

- What to you think of each of the 4 possible approaches? Are there any additional approaches you would suggest DEQ explore further?

- Do you think we have enough data to make a decision about which approach to take?

- What would the Board like to be taken on to support the PFAS effort?

Thank you.

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Department of Environmental Quality

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Keys to Toxicity Data Abbreviations and Computational Grouping Information

Supplementary Table 1- the ToxPrint Group information from Houck et al 2021.

code	ToxPrint Group Name	Casrn	Chemical name	abbrv	Notes
1	Perfluoroalkane sulfonate	3871-99-6	Potassium perfluorohexanesulfonate	PfHxS	salt form
		29420-49-3	Potassium perfluorobutanesulfonate	PFBS	salt form
		2795-39-3	Potassium perfluorooctanesulfonate	PFOS	salt form
		2806-15-7	Sodium perfluorodecanesulfonate	PFDS	not in NC table; salt form
2	Perfluorakyl (linear) sulfonates	1763-23-1	Perfluorooctanesulfonic acid	PFOS	
		355-46-4	Perfluorohexanesulfonic acid	PFHxS	
		375-92-8	Perfluoroheptanesulfonic acid	PFHpS	not in NC table
		375-73-5	Perfluorobutanesulfonic acid	PFBS	
5	Perfluoroalkyl ether carboxylates	62037-80-3	Ammonium perfluoro-2-methyl-3-oxahexanoate	Gen X	salt form
		55621-21-1	Perfluoro-3,6-dioxaoctane-1,8-dioic acid	PFDoDa	
		377-73-1	Perfluoro-3-methoxypropanoic acid	PFMOPra	
		801212-59-9	Perfluoro-4-isopropoxybutanoic acid	PFPE-1	not in NC table
		13252-13-6	Perfluoro-2-methyl-3-oxahexanoic acid	GenX	
7	Perfluoroalkyl (linear) Carboxylic Acids	422-64-0	Perfluoropropanoic acid	PFProA	not in NC table
		2706-90-3	Perfluoropentanoic acid	PFPeA	
		335-67-1	Perfluorooctanoic acid	PFOA	
		375-95-1	Perfluorononanoic acid	PFNA	
		307-24-4	Perfluorohexanoic acid	PFHxA	
		375-22-4	Perfluorobutanoic acid	PFBA	
		335-76-2	Perfluorodecanoic acid	PFDA	
		375-85-9	Perfluoroheptanoic acid	PFHpA	
9	Perfluoroalkyl carboxylic acids (PFCAs) their salts and esters	865-79-2	Chloro-perfluorononanoic acid	PFOA	salt form

Supplementary Table 2- Active site descriptive information abridged from Cheng and Ng 2019.

abridged from Cheng & Ng 2019

Target Class	Target	Description
G protein-coupled receptors (GPCRs)	NPSR	The neuropeptide S receptor (NPSR), which is highly expressed in brain areas involving modulation of arousal, stress and anxiety, could be a novel drug target for the treatment of sleep and anxiety disorders. This assay is conducted to identify NPSR antagonists.
	GLP-1	The overall aim of this assay is to discover ligands for class B1 GPCRs. Specifically, this assay focused on class B1 receptor for glucagon-like peptide-1 (GLP-1), which is a potential therapeutic target for diabetes and neurodegenerative disease.
ion channel	CNG	The cyclic nucleotide gated (CNG) ion channel was used as a biosensor for cAMP induction in this assay. The rationale is that cAMP stimulation will cause the CNG ion channel to open and subsequent membrane depolarization to occur.
miscellaneous	DNA re-replication	This assay is used to screen small molecules that induce DNA re-replication, which can cause the DNA damage response, arrest cell proliferation, and trigger apoptosis.
other enzymes	CYP2C9 , CYP3A4, CYP2D6	Cytochromes P450 (CYP) are a group of heme-thiolate monooxygenases that oxidize a variety of substances including steroids, fatty acids, and xenobiotics. In these assays, three different CYPs (CYP2C99, CYP3A410, and CYP2D611) were used to screen inhibitors and substrates for those CYP enzymes.
	ALDH1A1	Aldehyde dehydrogenase 1 (ALDH1A1) is an enzyme that oxidizes a variety of endogenous and exogenous aldehydes to the corresponding carboxylic acids and is the critical step for retinoic acid metabolism. In this assay, inhibitors of ALDH1A1 were identified.
	G9a	G9a is a histone methyltransferase that is responsible for histone H3 lysine 9 (H3K9) mono- and di-methylation. It has been recognized as a potential drug target for several human diseases, including cancer. The goal of this assay is to identify inhibitors of G9a.
promoter	ELG1	As the major subunit of a Replication Factor C-like complex, ELG1 is critical to ensure genomic stability during DNA replication14. This assay identifies small molecules that block ELG1 function.
	ATXN	Ataxin-2 protein (ATXN2) is encoded by the ATXN2 gene. The mutation in ATXN2 could cause Spinocerebellar ataxia type 2 (SCA2) disease. The objective of this assay is to identify compounds that inhibit the expression of ATXN2.
protein kinase	Plk1 PBD	Polo-like kinase 1 (Plk1) is a member of a conserved subfamily of serine / threonine protein kinases and plays a central role in cell proliferation. Plk1 is a potential target for anti-cancer therapy. This assay aimed to identify inhibitors that target the Plk1 polo-box domain (PBD).
protein-protein interaction	K18	In this assay, a recombinantly expressed fragment of tau, K18 was used to identify inhibitors of tau (which is an abundant protein in the axons of neurons that stabilizes microtubules) aggregation.
	HTTQ103	When exon 1 of HTTQ103 (Huntingtin protein containing 103 polyglutamines expansion) is expressed, it causes cell death and GFP aggregates. This assay screens for small molecules that reduce aggregate formation.
	JMJD2A	JMJD2A is a jumonji-domain-containing lysine demethylase. In this assay, the inhibitors of JMJD2A-tudor domain interactions (which is helpful in probing the regulatory pathways of selective demethylation of a given methyllysine locus) were identified20. signaling pathway Gsgsp The objective of this assay is to identify molecules with inhibitory activity at gsp mutations, which are responsible for McCune-Albright syndrome.
transcription factor	RORγ	The goal of this assay is to identify small molecules that inhibit ROR (retinoic acid-related orphan receptor) gamma activity.
	VP16	The goal of this assay is to identify small molecules that inhibit components common to both ROR gamma and VP16 transcription factor.
	Nrf2	Nrf2 is a transcription factor that maintains cellular redox homeostasis and protects cells from xenobiotics. This assay is used to screen inhibitors of Nrf2 function, which could be potential therapeutic targets for improvement in cancer treatment.
	Smad3	TGF-b signaling pathway plays important roles in cellular and development pathways. Smad3 is the primary transducer of TGF-b's signals and regulates many functions related to TGF-b signaling. The goal of this assay is to identify Smad3-small molecule antagonists.
viability	HT-1080-NT	In this assay, a synthetic lethal screen was conducted for chemical probes specific for 2HG-producing tumor cells using HT-1080-NT fibrosarcoma cell line.
	DT40-hTDP1*	Human tyrosyl-DNA phosphodiesterase 1 (HTDP1) is a novel repair gene and can be used as a new target for anti-cancer drug development. In this assay, after exposure to small molecules in the absence of camptothecin, the growth kinetics of DT40-hTDP1 cells were evaluated to determine whether the molecules can inhibit the TDP1-mediated repair pathway.
	DT40-hTDP1*	In this assay, after exposure to small molecules in the presence of camptothecin, the growth kinetics of DT40-hTDP1 cells were evaluated to determine whether the molecules can inhibit the TDP1-mediated repair pathway.