Case study of per-and polyfluoroalkyl substances (PFAS) from biosolids contaminating farmland in Johnson County, Texas
v.2 2/21/24

Background. Public Employees for Environmental Responsibility (PEER) was contacted by Investigator Dana Ames from the Johnson County Constable's Office, Environmental Crimes Investigations. Investigator Ames was concerned about horrific smells coming from a farm property in Grandview, Texas, after land application of biosolids from Synagro. At least 10 cows and a horse on an adjacent farm have died for unknown reasons. PEER assisted Investigator Ames in contracting with a private laboratory, Eurofins Lancaster, to test the biosolids, soil, pond water, well water, and tissue from catfish and dead calves on two adjacent farms that we suspected were impacted by the spreading of biosolids on an adjacent farm. Results indicated high levels of per- and polyfluoroalkyl substances (PFAS) in the soil, ponds, well water, and animal tissue. This report explains the concerns with PFAS in biosolids that are applied to agricultural lands and discusses the relevance of the PFAS found on the subject properties.

PFAS in biosolids. Biosolids, also known as sewage sludge, are the treated organic matter separated from human sewage waste; during the wastewater treatment process, liquids are separated from the solids, and the solids are treated to remove some of the toxic ingredients and reduce pathogens. Unfortunately, many of the pollutants in biosolids are not removed through treatment, and these chemicals enter the environment when biosolids are: 1) land applied to agricultural lands, home gardens, pastures, and other lands as fertilizer; 2) landfilled; or 3) incinerated.

Biosolids contain a variety of persistent and toxic pollutants, including PFAS, which then enter our water and food supply. PFAS get into biosolids in two ways. First, PFAS are ubiquitous in consumer products such as clothing, household cleaners, carpets, upholstered furniture, personal care products, and makeup. When people use these products, PFAS are washed down the drain and enter sewer systems, where they are sent to wastewater treatment plants (WWTPs). Second, many industries use PFAS, and their waste streams are also sent to WWTPs. While WWTPs do remove some of the chemicals in the wastewater, they do not remove PFAS. In fact, concentrations of PFAS are often higher in the effluent of WWTPs than the influent, indicating that precursor PFAS are forming new PFAS during the treatment.[1] Virtually all biosolids based fertilizers tested have been found to contain large amounts of PFAS (Figure 1, showing PFAS concentrations in biosolids in parts per billion).[2]

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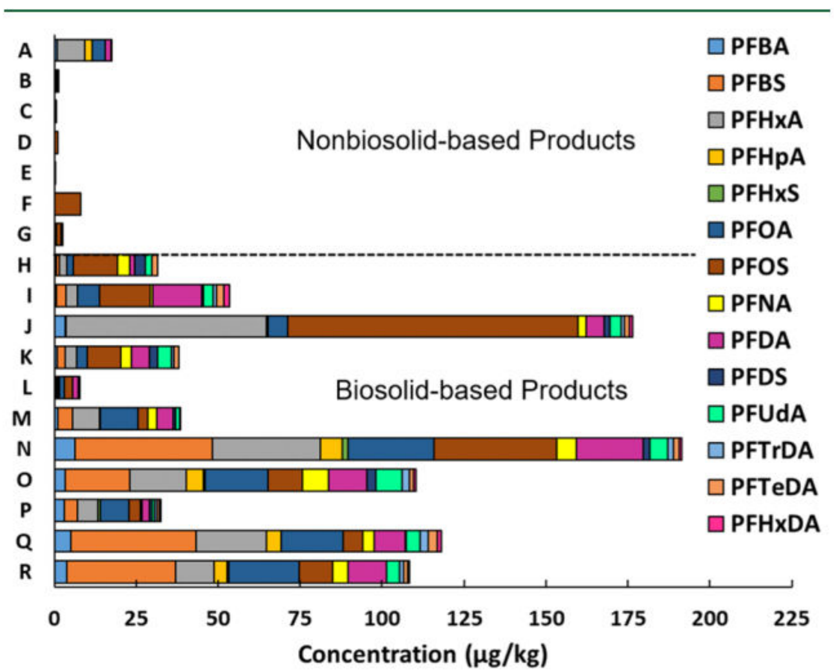
[1] https://apps.ecology.wa.gov/publications/documents/2110048.pdf

[2] Rooney Kim Lazcano, Youn Jeong Choi, Michael L. Mashtare, and Linda S. Lee, *Characterizing and Comparing Per- and Polyfluoroalkyl Substances in Commercially Available Biosolid and Organic Non-Biosolid-Based Products,* Environmental Science & Technology 2020 54 (14), 8640-8648, *DOI: 10.1021/acs.est.9b07281*

Figure 1



Why PFAS are of concern. PFAS are a large family of human-made chemicals, numbering between 6,504[3] and 12,034[4], that provide heat, stain, and water resistance. Yet, due to the strong carbon-fluorine bonds that occur in these molecules, PFAS do not easily break down in the environment and are called "forever chemicals." Well-studied PFAS are toxic to humans in concentrations as small as parts per quadrillion (ppq).[5] While the U.S. Environmental Protection Agency (EPA) does not have a consistent definition of PFAS, most states define PFAS as any chemical with at least one fully fluorinated carbon. Regardless of which definition is used, the adverse health impacts of PFAS are undeniable.

Specifically, PFAS are associated with cancer and are linked to growth, learning, and behavioral problems in infants and children; fertility and pregnancy problems, including pre-eclampsia; interference with natural human hormones; increased cholesterol; and immune system problems.[6] Epidemiological studies have found decreased antibody response to vaccines,[7] and associations between blood serum PFAS levels and both immune system hypersensitivity and autoimmune disorders like asthma and ulcerative colitis.[8] The negative immune system effects of PFAS are extremely concerning given the ongoing COVID-19 pandemic. Recently, the Centers for Disease Control and Prevention released a "Statement on Potential Intersection between PFAS

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[3] https://www.epa.gov/system/files/documents/2021-10/pfas-natl-test-strategy.pdf

[4] ENVTL. PROTECTION AGENCY, *PFAS Master List of PFAS Substances*, https://comptox.epa.gov/dashboard/chemical_lists/pfasmaster

[5] CAL. OFFICE OF ENVTL. HEALTH HAZARD ASSESSMENT, *Announcement of Availability of a Draft Technical Support Document and Public Workshop for Proposed Public Health Goals for Perfluorooctanoic Acid and Perfluorooctane Sulfonic Acid in Drinking Water*, (July 22, 2021) https://oehha.ca.gov/water/crnr/announcement-availability-draft-technical-support-document-and-public-workshop-proposed.

[6] U.S. Dept. of Health and Human Services, Agency for Toxic Substances and Disease Registry, *Toxicological Profile for Perfluoroalkyls*, (May 2021), https://www.atsdr.cdc.gov/toxprofiles/tp200.pdf

[7] Sunderland, E. M. et. al., *A Review of the Pathways of Human Exposure to Poly- and Perfluoroalkyl Substances (PFASs) and Present Understanding of Health Effects*, 29 JOURNAL OF EXPOSURE SCIENCE AND ENVIRONMENTAL EPIDEMIOLOGY, no. 2, (2018), https://pubmed.ncbi.nlm.nih.gov/30470793/.

[8] *See* U.S. Environmental Protection Agency, *Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA)*, 39 (May 2016), https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_health_advisory_final_508.pdf.

Exposure and COVID-19," which recognized the "evidence from human and animal studies that PFAS exposure may reduce antibody responses to vaccines . . . and may reduce infectious disease resistance."[9]

Numerous studies have found toxicity in legacy PFAS, such as PFOS and PFOA. Yet, as scientists study newer replacement PFAS, they are finding similar adverse toxicological outcomes in the new PFAS they test.[10] A compilation of PFAS toxicity studies shows that virtually every PFAS examined is correlated with adverse health outcomes.[11]

Routes of exposure for PFAS include ingestion, inhalation, and dermal absorption. While ingestion of PFAS is the most common route of exposure, scientists are finding that inhalation and dermal absorption are important routes of exposure. The federal Agency for Toxic Substances and Disease Registry (ATSDR) states that people working with PFAS "may be exposed to PFAS by inhaling them, getting them on their skin, and swallowing them."[12] Moreover, recent work shows that firefighters can be exposed to PFAS through "ingestion or inhalation, or direct contact with the skin and dermal absorption."[13] Recent studies have shown that some PFAS can migrate from car seat fabric to sweat, showing a potential dermal exposure route.[14] The State of Maine, concerned about the "surprising lack of empirical data on soil exposure by farmers and farm workers (e.g., incidental soil ingestion, dermal absorption, inhalation of re-entrained soil particles)" is conducting a study to determine the extent of PFAS exposure for farmers.[15]

Even minute amounts of PFAS are dangerous. In March of 2023, the U.S. Environmental Protection Agency (EPA) issued proposed drinking water limits for six PFAS, including PFOA and PFOS.[16] The proposed limits are 4 parts per trillion (ppt) for both PFOA and PFOS individually, but EPA also proposed health-based, non-enforceable Maximum Contaminant Level Goals (MCLGs) of *zero* because "there is no dose below which either chemical is considered safe."[17] The other four PFAS EPA proposes to regulate are GenX, PFBS, PFNA, and PFHxS.[18] Once these proposed regulations are finalized, all states will have to comply with them, including Texas. EPA is striving to finalize these regulations this calendar year.

PFAS biomagnifies in the food chain. PFAS in biosolids leach into the soil or ground water, are then taken up by plants, which are subsequently consumed by humans and wildlife. In 2021, scientists published an article that predicted PFAS uptake and concentrations in different plants from biosolids and calculated the potential exposure to humans and animals consuming harvested vegetation.[19] They determined that EPA's current daily reference doses of PFOA and PFOS (i.e., 20 ng/kg body weight for PFOA and 30 ng/kg body weight for

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[9] Centers for Disease Control and Prevention and Agency for Toxic Substances and Disease Registry, *Statement on Potential Intersection between PFAS Exposure and COVID-19*, https://www.atsdr.cdc.gov/pfas/health-effects/index.html (last visited Mar. 29, 2021).

[10] U.S. Dept. of Health and Human Services, National Toxicology Program, *Per- and Polyfluoroalkyl Substances (PFAS)*, https://ntp.niehs.nih.gov/whatwestudy/topics/pfas/index.html

[11] https://pfasproject.com/pfas-toxic-database/

[12] https://www.atsdr.cdc.gov/pfas/health-effects/exposure.html#:~:text=Workers%20may%20be%20exposed%20to,your%20body%20through%20your%20skin.

[13] https://www.sffcpf.org/wp-content/uploads/2020/06/6.23.2020-DR-PEASLEE-STUDY-ANOTHER-PATHYWAY-FOR-FIREFIGHTER-EXPOSURE-TO-PFAS-FIREFIGHTER-TEXTILES.pdf

[14] https://www.sciencedirect.com/science/article/abs/pii/S0269749120361650?via%3Dihub

[15] https://www.maine.gov/dacf/about/commissioners/pfasfund/docs/draft-all-plan-admin-of-pfasfund-final.pdf, p. 91

[16] https://www.epa.gov/sdwa/and-polyfluoroalkyl-substances-pfas

[17] https://www.federalregister.gov/documents/2023/03/29/2023-05471/pfas-national-primary-drinking-water-regulation-rulemaking

[18] EPA is regulating these four PFAs with a Hazard Index, which is explained here: https://www.epa.gov/system/files/documents/2023-03/How%20do%20I%20calculate%20the%20Hazard%20Index._3.14.23.pdf

[19] Lasee, S. et al, *The Effects of Soil Organic Carbon Content on Plant Uptake of Soil Perfluoro Alkyl Acids (PFAAs) and the Potential Regulatory Implications,* Environmental Toxicology and Chemistry, Vol 40(3), pp 832-845 (2021).

PFOS)[20] could be met by consuming vegetables grown in biosolid amended soils.[21] In other words, eating vegetables grown in biosolid-amended soil could be dangerous.

Because PFAS can biomagnify,[22] PFAS from soil can be taken up by plants, which are then eaten by animals such as cows, creating contamination of both the milk and the meat. Similarly, if water is contaminated with PFAS, fish in those waters also become contaminated. Moreover, recent research shows PFAS can lead to acute toxicity and result in fish kills.[23] PFAS are considered proteinophilic;[24] that is, they partition to blood, muscle, liver, and other high protein tissues. Farms and communities can be devastated by the subsequent contamination of water, soil, crops, fish, and livestock.

The problem of PFAS in biosolids is not new. A 2013 study of biosolids archived from 2001 showed massive quantities of PFAS in all samples.[25] Farmers in Michigan,[26] New Mexico,[27] and Maine[28] are being forced to shut down operations due to PFAS contamination. Some of these farms became contaminated with PFAS from the spreading of biosolids years ago. Despite this known problem of PFAS-laden biosolids contaminating farms, only Maine has attempted to address the problem. In 2022, Maine passed a law that prohibits the land application of biosolids.[29]

Approximately one-quarter of biosolids in the United States are applied to farms. According to the EPA, roughly 25% of the nation's biosolids are applied to agricultural fields (Figure 2).[30] In 2021, there were approximately 4.5 Million Dry Metric Tons (mdmt) of biosolids generated in the United States; therefore, 1.15 mdmt were applied to agricultural fields. Biosolids are considered a cost-effective way to fertilize soils, while simultaneously solving the problem of what do with the millions of tons of waste generated each year.[31]

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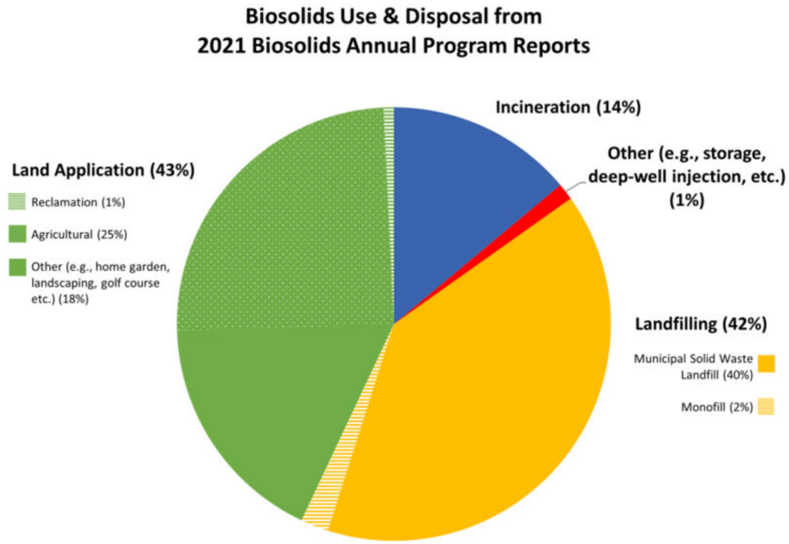
[20] On June 21, 2022, EPA updated its health advisories for PFOA and PFOS to 0.004 parts per trillion (ppt) for PFOA, 0.02 ppt for PFOS, 10 ppt for GenX chemicals, and 2,000 ppt for PFBS. *Lifetime Drinking Water Health Advisories for Four Perfluoroalkyl Substances*, 87 Fed. Reg. 36848. EPA's previous lifetime health advisory was 70 parts per trillion for both PFOA and PFOS.
[21] Id.
[22] Biomagnification is when the chemical concentration in an organism exceeds the concentration of its food when the major exposure route occurs from the organism's diet.
[23] Maysa Ueda de Carvalho, Lucas Buruaem Moreira, Denis Moledo de Souza Abessa,
Are fire suppressants "nontoxic"? Acute toxicity, DNA damage and lipid peroxidation in fish (Poecilia reticulata) exposed to low concentrations, Journal of Hazardous Materials Advances, Volume 9, 2023, 100238, ISSN 2772-4166, https://doi.org/10.1016/j.hazadv.2023.100238 and Lu H, Zhou JY, Yang F, et al., Ecological Toxic Effect of Perfluorinated Compounds on Fish Based on Meta-analysis, 2023 Sep; 44(9):5231-5241. DOI: 10.13227/j.hjkx.202209239. PMID: 37699841.
[24] Peritore AF, Gugliandolo E, Cuzzocrea S, Crupi R, Britti D. *Current Review of Increasing Animal Health Threat of Per- and Polyfluoroalkyl Substances (PFAS): Harms, Limitations, and Alternatives to Manage Their Toxicity.* Int J Mol Sci. 2023 Jul 20;24(14):11707. doi: 10.3390/ijms241411707.
[25] Venkatesan, AK, Halden, RU. *National inventory of perfluoroalkyl substances in archived U.S. biosolids from the 2001 EPA National Sewage Sludge Survey*. J Hazard Mater. 2013 May 15;252-253:413-8. doi: 10.1016/j.jhazmat.2013.03.016.
[26] https://www.dtnpf.com/agriculture/web/ag/livestock/article/2022/05/06/michigan-farm-cautionary-tale-pfas#:~:text=States%20such%20as%20Michigan%20have,that%20their%20soils%20are%20contaminated.
[27] https://www.agri-pulse.com/articles/17916-new-mexico-dairy-farmer-awaits-pfas-relief-as-congress-looks-to-boost-research-funding
[28] https://www.mainepublic.org/environment-and-outdoors/2023-02-01/more-than-50-maine-farms-impacted-by-pfas-but-state-officials-see-glimmer-of-hope
[29] https://legislature.maine.gov/legis/bills/getPDF.asp?paper=HP1417&item=7&snum=130
[30] https://www.epa.gov/biosolids/basic-information-about-biosolids
[31] https://www.sciencedirect.com/science/article/pii/S0048969723011713

Figure 2



The fate of PFAS depends on chain length. PFAS are often categorized by carbon chain length. Since all PFAS have a carbon-fluorine "backbone," the number of carbons is an important factor in their environmental fate. Generally, PFAS with six or more carbons are considered long-chain PFAS, while those with fewer than six carbons are considered short-chain. The two most studied PFAS are eight carbon PFAS, PFOA and PFOS. Typically, the longer chain PFAS preferentially partition to sediments, while the shorter chain PFAS remain dissolved in water. However, longer chain PFAS in the soil can provide a secondary source of shorter chain PFAS as they slowly degrade.

At least 11 PFAS in biosolids should be banned from land application. PEER believes that at least 11 PFAS identified in biosolids have sufficient scientific information, including concentration data, human health toxicity data, ecological toxicity data, and environmental fate and transportation data, showing that these PFAS may adversely affect public health and the environment, should be banned from land application. Those PFAS are: 1) PFBS; 2) PFHxA; 3) PFHxS; 4) PFHpA; 5) PFOA; 6) PFOS; 7) PFNA; 8) PFDA; 9) PFUnDA; 10) PFDoDA; and 11) PFBA.

Various studies, conducted from 2005 to 2021 by EPA and others, have shown both human health toxicity data and environmental fate and transport data for each above listed PFAS. Of these 10 PFAS, we found extremely high concentrations of nine of them on the two subject properties in Grandview, Texas (see Appendix 1).

Human health and toxicity data for these 11 PFAS. PFOA and PFOS are extremely well studied due to a settlement agreement in a lawsuit against DuPont in 2002.[32] It is now known that these two PFAS are carcinogenic. The remaining nine PFAS have varying numbers of studies showing health effects (Figure 3).[33]

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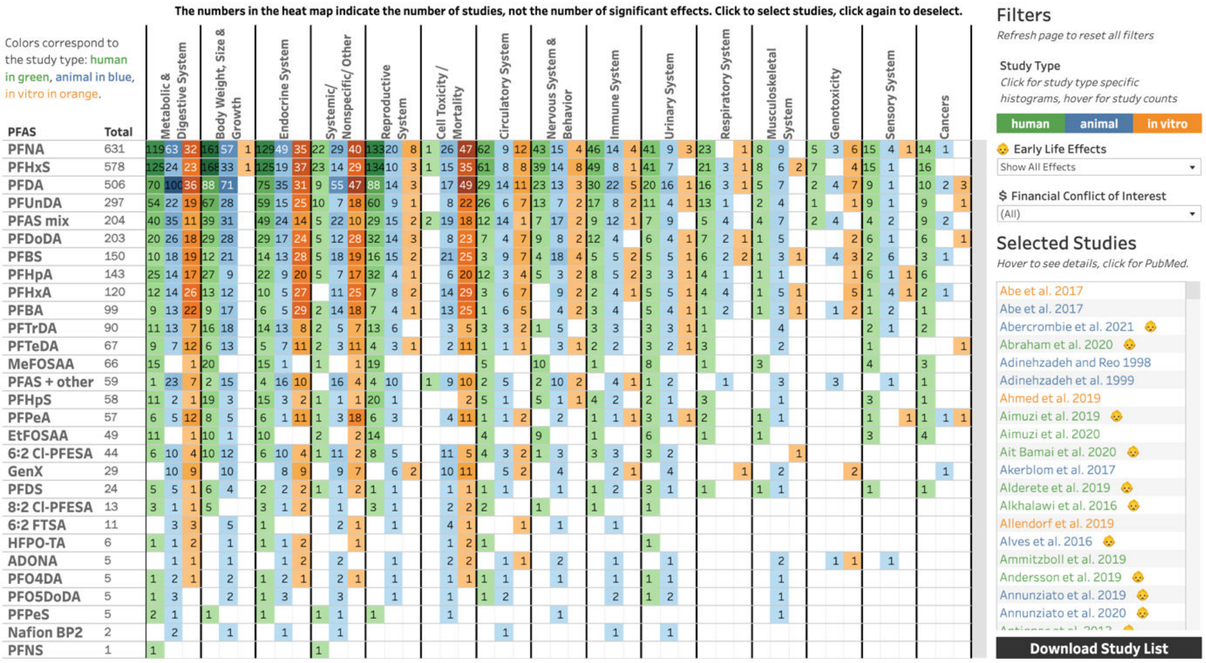
[32] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2799461/
[33] https://pfastoxdatabase.org/

Figure 3



Levels of PFAS found on the subject properties are of concern. The levels of PFAS found on the subject properties are of concern (Appendix 1). Thirty-two individual PFAS were found in the soil and water. In this chart, the PFAS that PEER believes should be regulated by EPA in biosolids are shown highlighted in turquoise. Ten of the eleven PFAS we believe EPA should be regulating were found on the properties in question. *All* the sites tested had at least one PFAS.

It is worth noting the extremely high levels of PFPrA, a short-chain PFAS that is a degradation product of GenX. EPA's reference dose (RfD)[34] for PFPrA is 0.0005 mg/kg bw-day.[35] The RfD for PFPrA is going to be re-examined; but these levels are of concern given that we know very little about the health effects of this particular PFAS. Site 12, Sample 1-A is a drinking water well, so the PFAS in this sample are being consumed on a daily basis. We did find very small amounts of PFPrA in a few of our material blanks, but the levels of this PFAS found in the soil and water samples were so high that they could not have come from contamination.

PFAS in the biosolids. The biosolids that were land applied to the farm in Grandview were from Synagro, which obtains its sludge from the Fort Worth, Texas Biosolids Processing Facility. Although we were unable to obtain a sample of these biosolids directly from the facility, we obtained a jar of the biosolids given to reporters during a press event on December 1, 2022. The jar was never opened, and remained on the reporter's desk for roughly one year (see Photograph 1, below).

Photograph 1

[34] A RfD is an estimate of a daily exposure to the human population (including sensitive subpopulations) that is likely to be without an appreciable risk of deleterious effects during a lifetime.
[35] https://www.cfpua.org/CivicAlerts.aspx?AID=1475

These results are shown in Appendix 2. Twenty-seven individual PFAS were found; the PFAS that were also found in the soil and water on the subject properties are highlighted in green. Thirteen (13) of the PFAS found in the biosolid sample were also found in the soil and water samples on the subject properties; of those 13, eight are on our list of PFAS EPA should be regulating (PFHxA; PFHxS; PFOA; PFOS; PFNA; PFDA; PFUnDA; and PFDoDA).

PFAS in catfish and beef on subject properties. Shortly after the first known application of biosolids on the adjacent farm in 2016, the catfish on one of the subject properties experienced a massive fish kill (biosolids were also spread on the property in 2018 and 2022). Although those dead fish were disposed of, two of the replacement fish were tested for PFAS levels in 2023. In addition, one of the newborn calves died suddenly on the second subject property at approximately one week of age. Another calf was stillborn. Tests were conducted on the meat of both calves, and the liver of the stillborn calf. Those results are found in Appendix 3.

The levels of just PFOS in the fish are staggering (74,000 ppt and 57,000 ppt, respectively). To put this in perspective, EPA stated in March of 2023 that, "there is ***no dose*** below which either … [PFOA or PFOS] is considered safe…" for consumption (emphasis added).[36] These fish should not be eaten. Note that in US, fish tested between 2013 and 2015 had median levels of PFAS of 11,800 ppt.[37]

Although the PFAS levels in the calf were much lower, it still had concerning levels of PFAS (including PFPrA) in its meat. The calf was still nursing, but also eating some forage and water; therefore, this PFAS was from both its mother's milk and from forage or water.

In comparison, PFAS found in a stillborn calf were entirely from the mother (via the placenta) (Appendix 4). The stillborn calf's liver had 610,000 ppt of PFOS, which is extremely high, and indicates that the adult cows are exposed to very high levels of PFAS in their water and forage. It is likely that fully grown cattle will have much higher levels of PFAS in their flesh.

[36] https://www.federalregister.gov/documents/2023/03/29/2023-05471/pfas-national-primary-drinking-water-regulation-rulemaking#:~:text=Considering%20feasibility%2C%20including%20currently%20available,ppt)%20for%20PFOA%20and%20PFOS.

[37] Barbo, N., T. Stoiber, O.V. Naidenko, D.Q. Andrews, Locally caught freshwater fish across the United States are likely a significant source of exposure to PFOS and other perfluorinated compounds, Environmental Research, Volume 220, 2023, 115165, ISSN 0013-9351, https://doi.org/10.1016/j.envres.2022.115165.

The levels of PFOS in the animal tissue exceeds both the Texas and EPA RfDs, and the PFHxS levels exceed the TCEQ RfD. The Texas Commission on Environmental Quality (TCEQ) have reference doses (RfDs)[38] for PFOS and PFHxS, two PFAS found in the animal tissue.

TCEQ's RfD for PFOS is 23 ng/kg/day. In a 70 kg adult, this translates to 1610 ng. The EPA interim RfD for PFOS is 0.0079 ng/kg/d. In a 70 kg adult this translates to 0.553 ng; therefore, a single 8 oz (225 gram) serving of the tissues translates to a PFOS exposure of:

- Fish 1: 74 ng/g x 225 g = 16,650 ng (10.3x the Texas RfD; 30,000x the EPA RfD)
- Fish 2: 57 ng/g x 225 g = 12,825 ng (8.0x the Texas RfD; 23,000x the EPA RfD)
- Week old calf: 0.32 ng/g x 225 g = 72 ng = (0.4x the Texas RfD; 130x the EPA RfD)
- Calf Liver: 610 ng/g x 225 g = 137,250 ng (85x the Texas RfD; 250,000x the EPA RfD)

TCEQ's RfD for PFHxS is 3.8 ng/kg/d, which is equal to 266 ng daily exposure for a 70 kg adult. The calf liver had significant concentrations of PFHxS, translating to a PFHxS exposure of:

- A single 8 oz (225 gram) serving of the calf liver (1.3 ng/g PFHxS) would translate to an exposure of 292.5 ng, 1.1x the Texas RfD (the EPA does not currently have a RfD for PFHxS).

Therefore, eating either fish or the calf liver exceeds what TCEQ and EPA consider safe for PFOS; eating the calf muscle exceeds EPA's RfD for PFOS. Similarly, eating the calf liver exceeds what TCEQ considers safe.

Conclusion. The PFAS levels found on the subject properties are of concern. PEER believes that the amount of PFAS found could have caused the fish kill on the property, may be contributing to or causing the deaths of the cows, and that the application of biosolids on the adjacent property is causing these high levels of PFAS. Tests of the fish and deceased cows are pending. It is critical to note that each subsequent application of biosolids will increase the levels of PFAS in these soils and waters, and exacerbate existing problems. Finally, and perhaps most importantly, the well water is unsafe and should not be consumed without filtration.

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Director, Science Policy
PEER
February 15, 2024

[38] An RfD is an estimate of a daily oral exposure for a chronic duration to the human population that is likely to be without an appreciable risk of deleterious effects during a lifetime.

APPENDIX 1

TEXAS PFAS RESULTS: Texas PFAS results in soil, pond water, tap water, and biosolids (reported in ppt)

PFAS (in ppt)	Site 2 (soil)	Site 6 Gully (soil)	Site 5 Gully (soil)	Site 3 Easement (soil)	Site 1 Easement (soil)	Site 4 (soil)	Site 8 Sample 1-A (pond water)	Site 12 Sample 1-A (pond water)	Site 7 (soil)	Site 11 Sample 1-A (pond water)	Site 10 Sample 1-A (well water)	Site 9 Sample 1-A (pond water)	Site 13 Sample 1 (soil)	Site 14 Sample 1A (well water)	Site 15 Sample 1A (pond water)	Sample 16 Biosolids
PFOS	99	110	79	19	280	90	1.3			0.51		1.3			0.49	13,000
PEPA	160	190	64	34												
NMeFOSA	140			58					190			1.8				
PFOA	72	33	48		110		3			1.8		0.39			1.4	560
PFDA	42	30	33	56	110	32	2			0.57		0.65				1,600
PFDoA (aka PFDoDA)					55											690
PFBA	42						9.6	1.8		5.7	3.5	9.1	28	3.1	9	
PFNA	52		39	77	72	46	1			0.57					0.38	320
PFPrA	3100	2500	3200	2600	5100	3000	770	180	2600	65	72	1,300	56	260	260	
HFPODA (aka GenX)						540	0.53									
6:2 FTCA	48	54	33	18		36	1.2		29			1.3				280
PFPeA				42	49		5.5			1.8		4.3			2.8	170
PFHxA				42			4.3			1.2		6.8			1.2	680
NMeFOSE				3300					33							1,100
PFHpA				45			2.8			0.87		1.3			1.4	
PFHxS												0.33				300
Hydrolyzed PSDA					54											
PFBS							2.8			0.44		2.6			0.48	
PFDOS							0.31									
FOSA (PFOSA)							3.7	1.3		0.49	1.4	0.5				260
PFO2HxA							0.48			2.2		0.36			8.8	
PMPA							1.3			2.8	0.9	1.7				
R-EVE							0.5									
PFMOAA								0.51		0.75	1.1					
PFO3OA																
PEPA								9.1	31		12			5.1		
7:3 FTCA									48							2,400
PFPrS												0.5				
R-PSDA												0.68				
PFODA													13			170
PFMOBA															0.82	
PFO4DA															2.8	
6:2 FTS																420
8:2 FTS																410
NEtFOSAA																720
NEtFOSE																660
NMeFOSAA																1,600
PFDS																310
PFHxDA																190
PFNS																110
PFTreA																200
PFUnA or PFUnDA																380
8:2 FTCA																140
8:2 FTUCA																280
6:2 FTUCA																660
5:3 FTCA																8,000
TOTAL PFAS	3,755	2,917	3,496	6,291	5,830	3,744	810.32	192.7	2,931	84.7	90.9	1,333.61	97	268.2	289.57	

Appendix 2: **PFAS in biosolids (reported in ppt)**

PFAS	ppt
6:2 Fluorotelomer sulfonic acid (6:2 FTS)	420
8:2 Fluorotelomer sulfonic acid (8:2 FTS)	410
NEtFOSAA	720
NEtFOSE	660
NMeFOSAA	1,600
NMeFOSE	1,100
Perfluorodecanesulfonic acid (PFDS)	310
Perfluorodecanoic acid (PFDA)	1,600
Perfluorododecanoic acid (PFDoA)	690
Perfluorohexadecanoic acid (PFHxDA)	190
Perfluorohexanesulfonic acid (PFHxS)	300
Perfluorohexanoic acid (PFHxA)	680
Perfluorononanesulfonic acid (PFNS)	110
Perfluorononanoic acid (PFNA)	320
Perfluorooctadecanoic acid (PFODA)	170
Perfluorooctanesulfonamide (PFOSA)	260

Perfluorooctanesulfonic acid (PFOS)	13,000
Perfluorooctanoic acid (PFOA)	560
Perfluoropentanoic acid (PFPeA)	170
Perfluorotetradecanoic acid (PFTreA)	200
Perfluoroundecanoic acid (PFUnA or PFUnDA)	380
7:3 FTCA	2,400
8:2 FTCA	140
6:2 FTCA	280
8:2 FTUCA	280
6:2 FTUCA	660
5:3 FTCA	8,000
TOTAL PFAS	35,330

Appendix 3: PFAS levels in catfish and week old calf

PFAS (in ppt)	Fish #1	Fish #2	Calf
PFHxS	120		
PFHpA	150		
PEPA	190		
PFOS	74,000	57,000	320
PFBA			480
PFPrA			2,400

Appendix 4: PFAS levels in stillborn calf

PFAS (in ppt)	Stillborn calf tissue	Stillborn calf liver
NEtFOSAA	170	
NMeFOSAA	170	
PFHxDA	110	
PFODA	160	
PFTrDA	130	
7:3 FTCA	180	
8:2 FTCA	110	
10:2 FTCA	140	
8:2 FTUCA	130	
10:2 FTUCA	190	
NMeFOSE		310
PFDA		250
PFHxS		1,300
PFOA		98
PFPeA		210
6:2 FTCA		130
NVHOS		110
PMPA		110
MTP		710
PFOS		610,000