Deriving PFOS soil screening levels for a soil-to-fodder-to-cow's milk agronomic pathway

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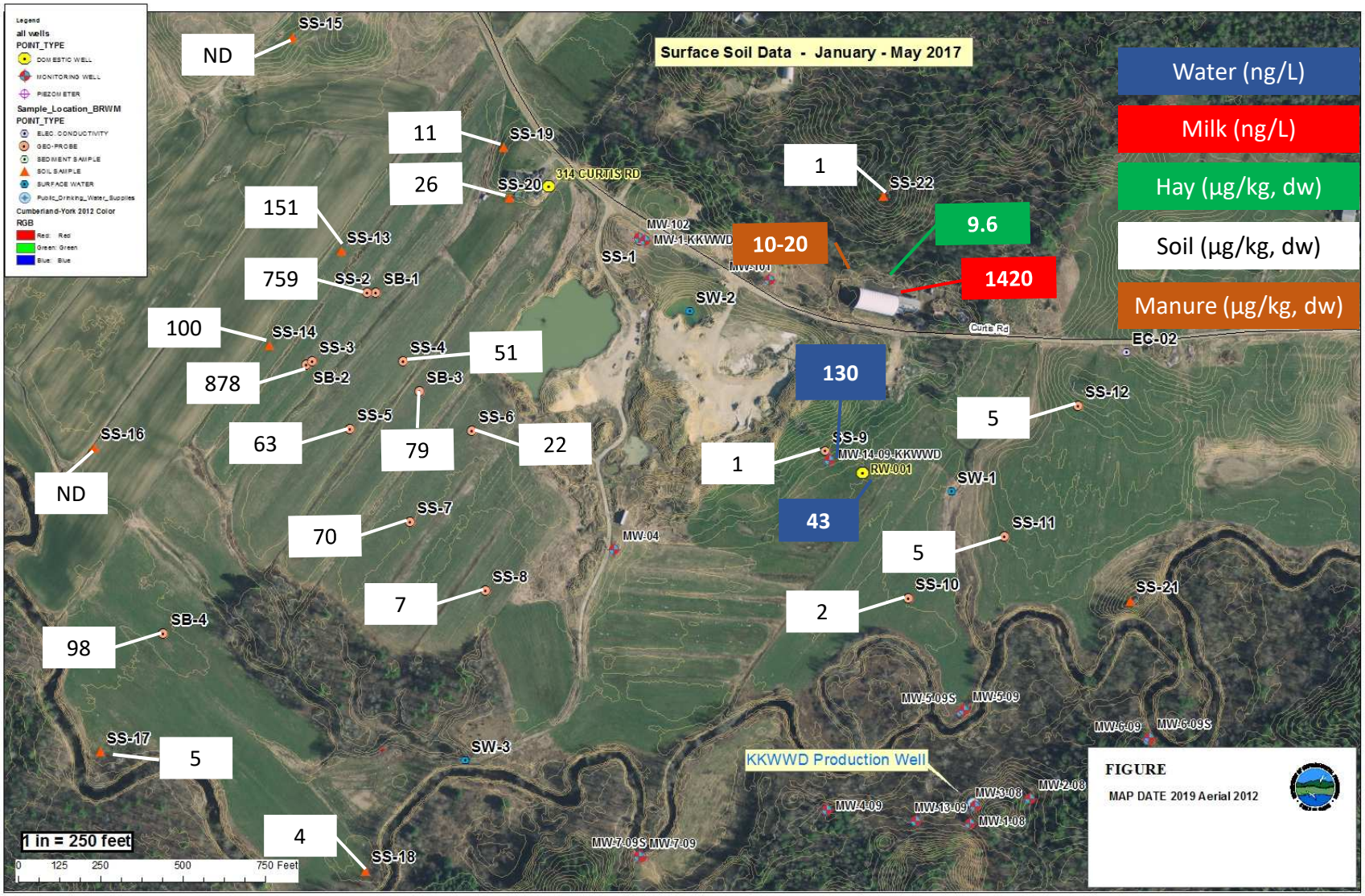
PFOS Contamination of Dairy Farms
- Stoneridge Farm, Maine -



Action Level for “adulterated” Milk

Toxicity Value
20 ng/kg/day

90th Percentile
Milk Intake
0.074 L/kg/day

1-2 year old

270 ng/L

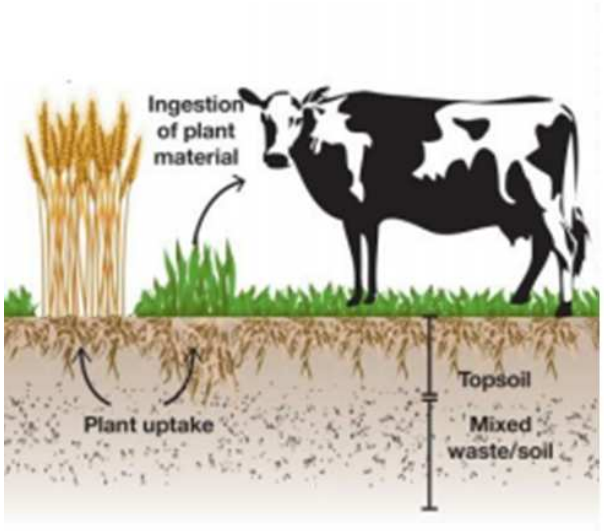
Milk Exposure Limit

Relative Source Contribution 80%

210 ng/L

Action Level

Agronomic Exposure Pathway



Soil ⇨ Hay/Corn ⇨ Cow ⇨ Milk ⇨ Child

Modified EPA Soil Screening Level Equation

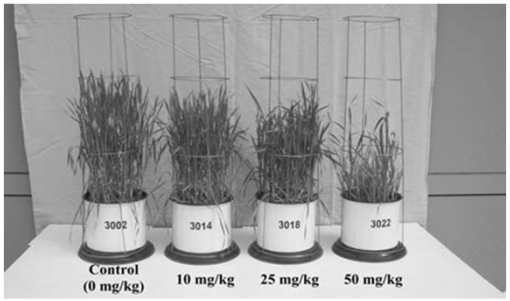
Milk Action Level "adulterated" — Milk density

$$SL_{soil} = \frac{C_{milk} \times (D_{milk})^{-1}}{TF_{milk} \times \left[\left(I_{fodder} \times F_{land-f} \times F_{year-f} \times \left(TF_{plant} + MLF\right)\right) + \left(I_{soil} \times F_{land-g} \times F_{year-g}\right)\right]}$$

Transfer factor intake to milk — **Feed ingestion rate** — Fraction of time exposed to contaminated feed — **Plant transfer factor** — **Soil mass loading factor** — **Soil ingestion rate** — Fraction of time exposed to contaminated soil

Source:
Modified equation from U.S. EPA Preliminary Remediation Goals for Radionuclides, consumption of milk back calculated to soil - https://epa-prgs.ornl.gov/radionuclides/users_guide.html

PFOS Hay Transfer Factor from Literature



Field studies

$TF_{hay} = 0.07 \pm 0.04\ (SD)$

$TF_{hay} = 0.14 \pm 0.11\ (SD)$

Potted-plant studies

$TF_{hay} = 0.58 \pm 0.9\ (SD)$

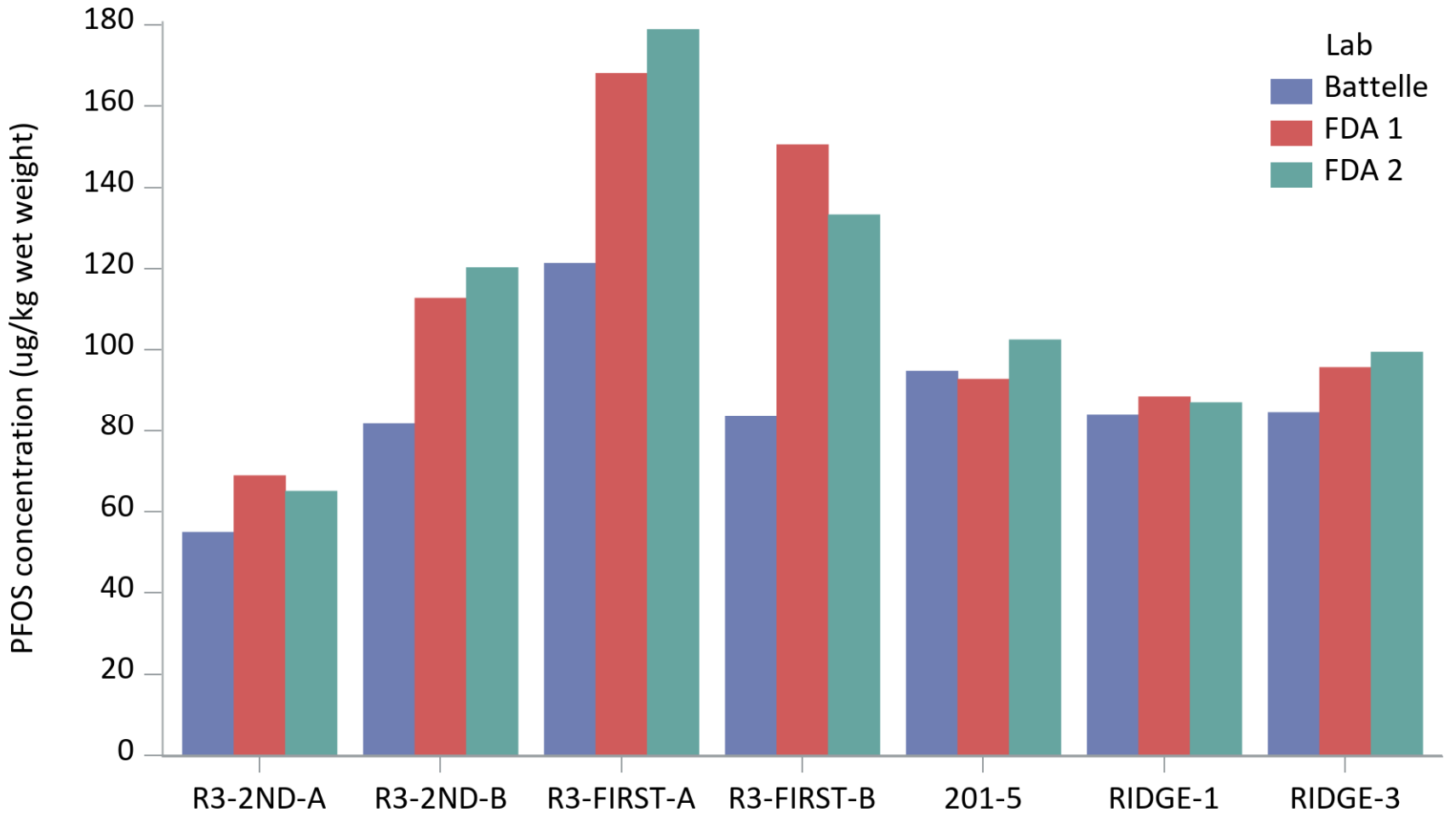
Source:
Yoo et al. 2011. https://doi.org/10.1021/es102972m
Fischer et al. 2008/2009 https://www.lanuv.nrw.de/fileadmin/lanuv/verbraucher/pdf/transfer_pft.pdf
https://www.lanuv.nrw.de/fileadmin/lanuv/verbraucher/pdf/transfer_pft_2008.pdf
Stahl et al. 2009. https://doi.org/10.1007/s00244-008-9272-9

Maine Hay PFOS Uptake Study

Field studies

$$TF_{hay} = 0.37 \pm 0.17 \text{ (SD)}$$

Grass PFOS Laboratory Confirmation Results



PFOS Corn Transfer Factor from Literature

Field studies

$TF_{corn} = 0.04 \pm 0.03\ (SD)$

$TF_{corn} = <0.08$

Potted-plant studies

$TF_{corn} = 0.16 \pm 0.04\ (SD)$

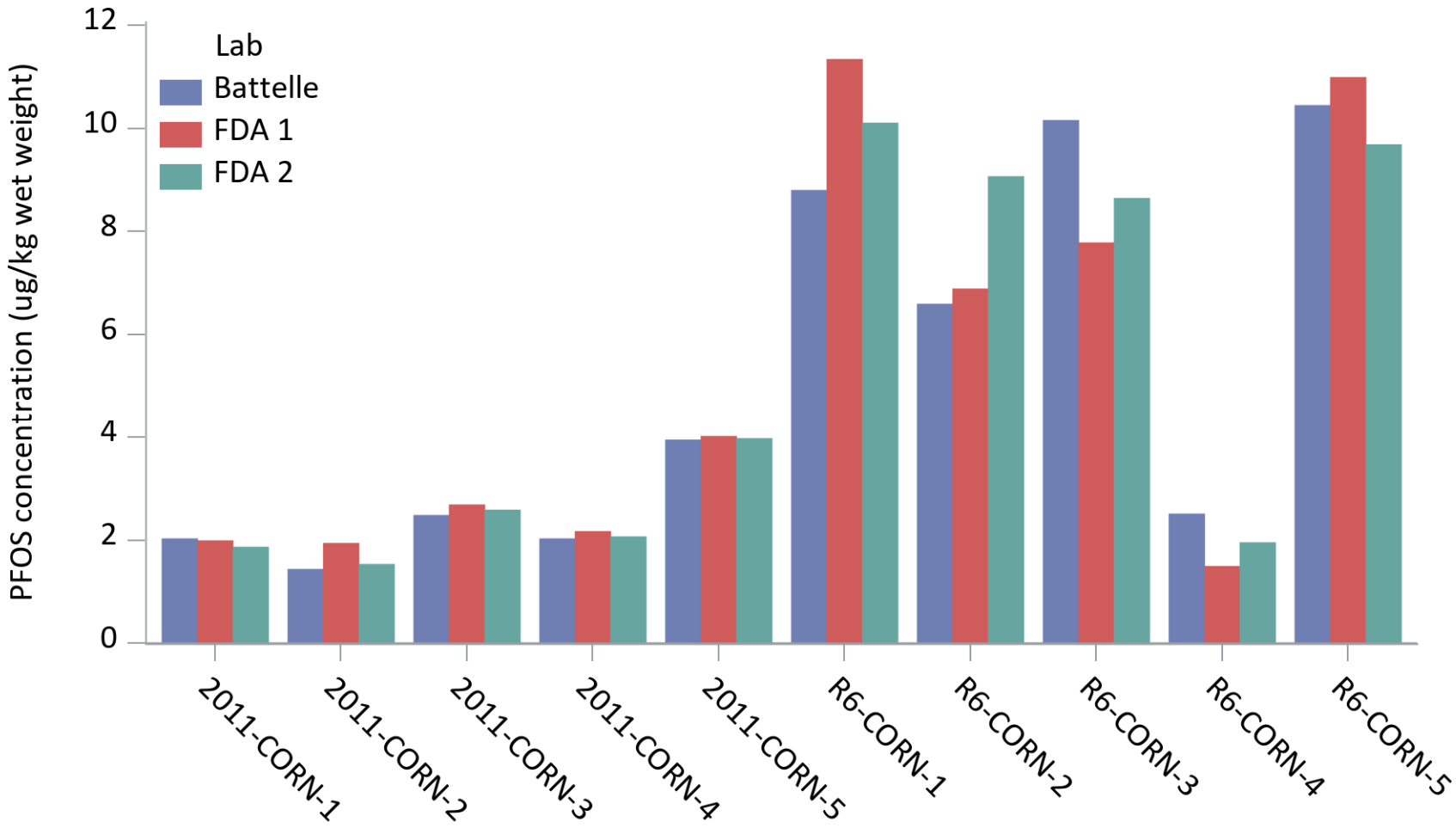
Source:
Fischer et al. 2008/2009 https://www.lanuv.nrw.de/fileadmin/lanuv/verbraucher/pdf/transfer_pft.pdf
https://www.lanuv.nrw.de/fileadmin/lanuv/verbraucher/pdf/transfer_pft_2008.pdf
Blaine et al. 2013 https://doi.org/10.1021/es403094q
Stahl et al. 2009. https://doi.org/10.1007/s00244-008-9272-9

Maine Corn PFOS Uptake Study

Field studies

$$TF_{corn} = 0.05 \pm 0.03 \text{ (SD)}$$

Corn PFOS Laboratory Confirmation Results



Plant Soil Mass Loading Factor

Processes for transfer of soil to plant surface

- Rain splash
- Wind erosion
- Soil disturbance by mechanical equipment

USEPA PRGR

- Default = 0.25, range 0.001 to 0.5
- Geometric mean of 11 studies = 0.034 (pasture plants only)

$$MLF_{grass} = 0.034^{*}$$

$$MLF_{corn} = 0.0014^{**}$$

Source:

*Hinton, T.G. 1992. Contamination of plants by resuspension: a review, with critique of measurement methods. Sci Total Environ. 121:117-193. DOI: https://doi.org/10.1016/0048-9697(92)90314-I

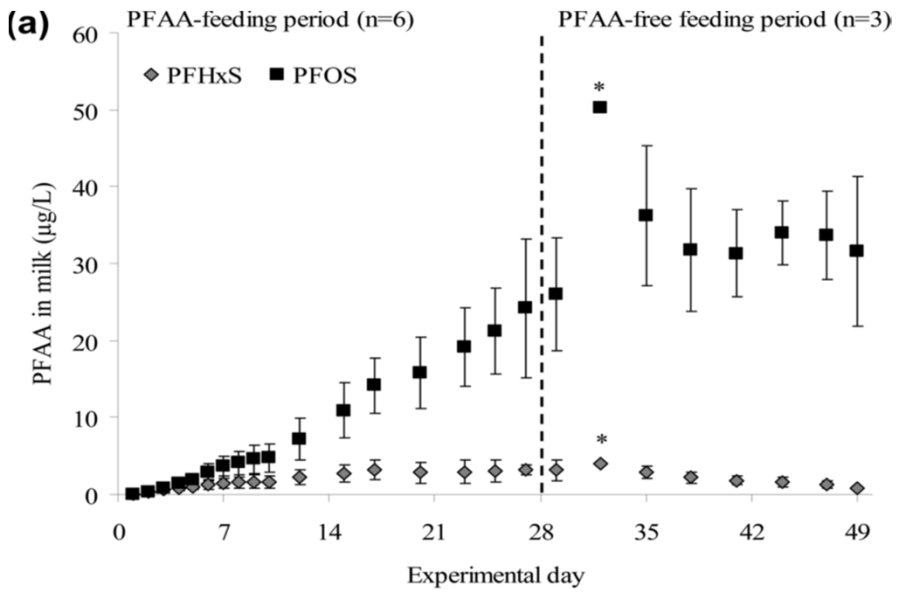
**Pinder III, J.E. et al. 1989. Mass loading of soil particles on plant surfaces. Health Physics. 57(6):935-942.

Soil Ingestion while Grazing

Grass-based Dairy Farm	"Average" Maine Dairy Farm
I_{soil} =0.26 kg/day	I_{soil} = 0.13 kg/day

I_{soil} = 2% of total dry matter intake

PFOS Milk Transfer Factor



German controlled feeding study

- Calculated TF_{milk} = 0.005
- Modeled TF_{milk} = 0.02 to 0.08

Swedish farm background study

- Calculated TF_{milk} = 0.02

$$TF_{milk} = 0.02$$

Source:

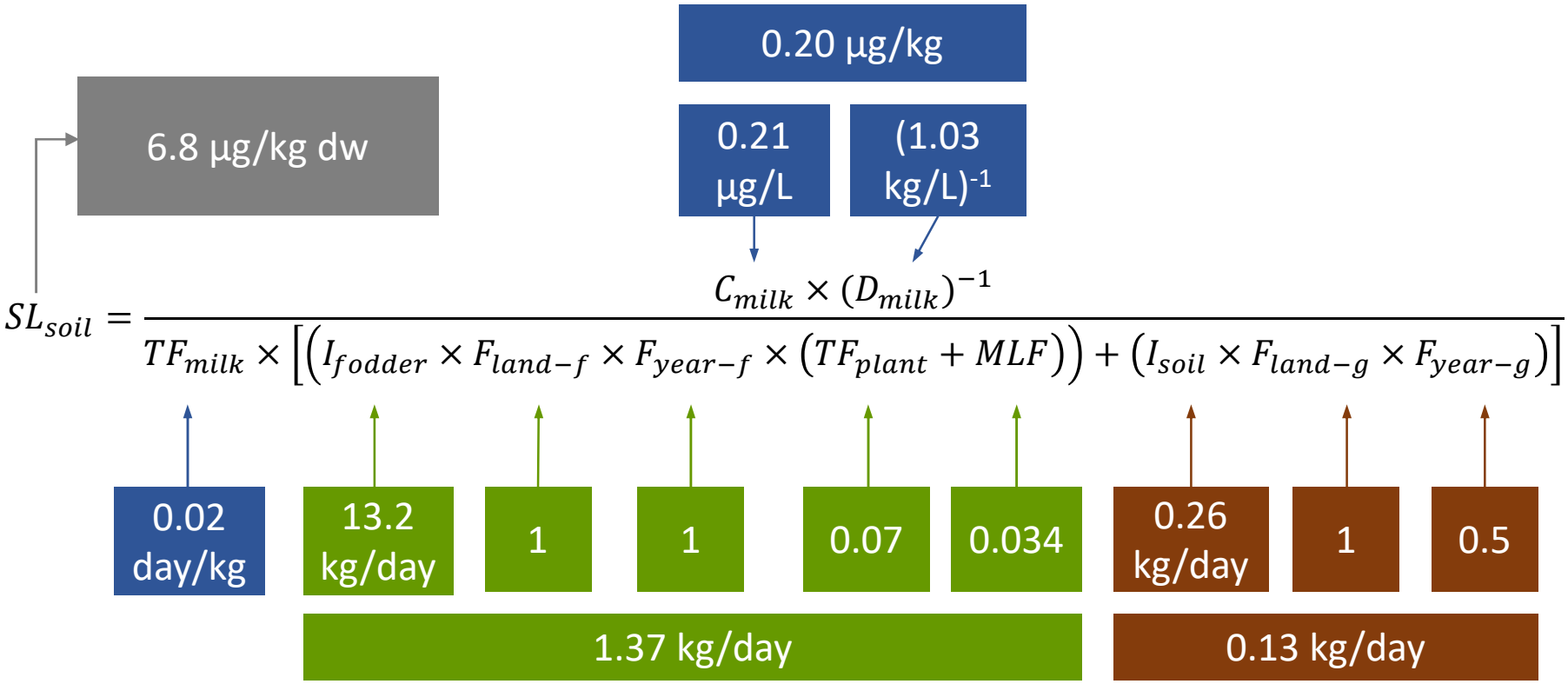
Kowalczyk et al. 2013. Absorption, distribution, and milk secretion of the perfluoroalkyl acids PFBS, PFHxS, PFOS, and PFOA by dairy cows fed naturally contaminated feed. J Agric Food Chem. 61(12):2903-12. https://doi.org/10.1021/jf304680j

Vestergren et al. 2013. Bioaccumulation of perfluoroalkyl acids in dairy cows in a naturally contaminated environment. Environ Sci Pollut Res Int. 20(11):7959-69. https://doi.org/10.1007/s11356-013-1722-x

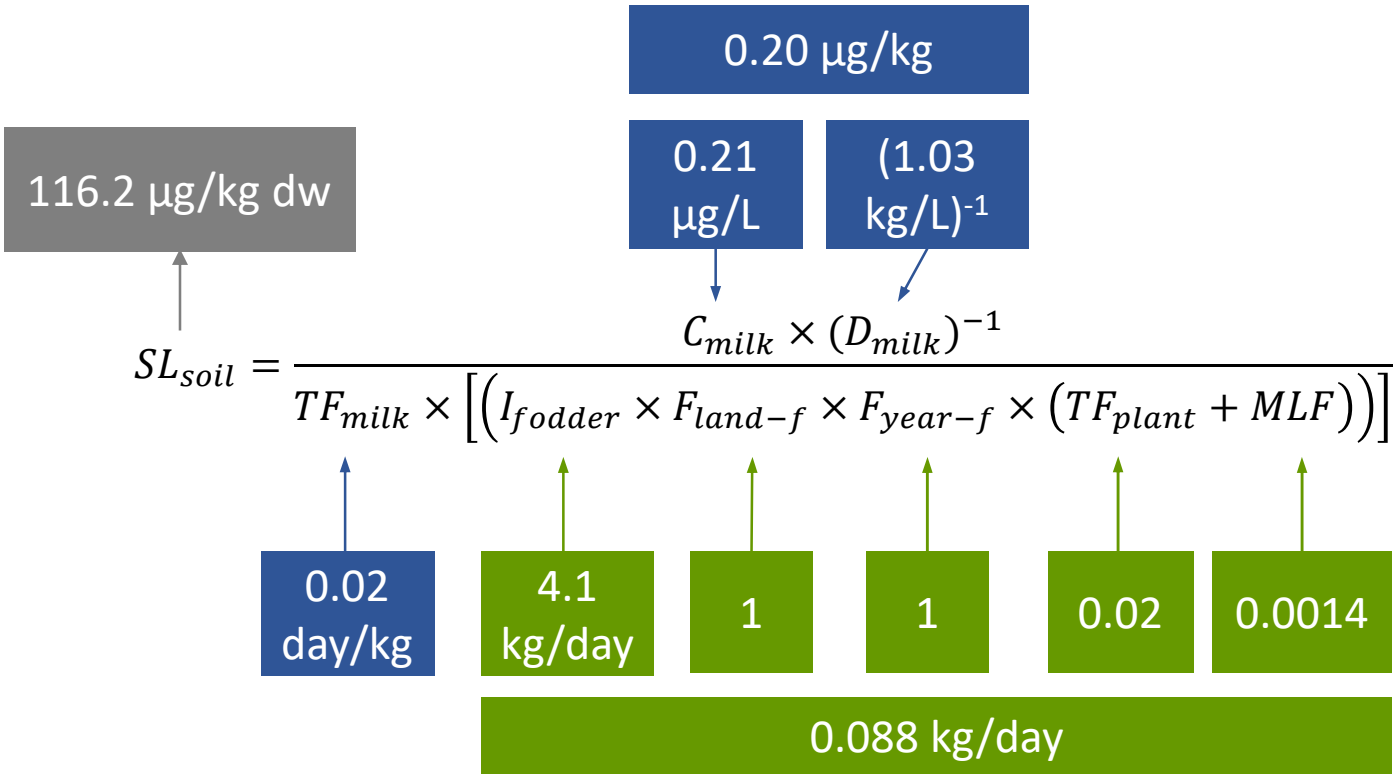
Dairy Farm Exposure Scenarios Fodder Intakes

Grass-based Dairy Farm	"Average" Maine Dairy Farm
Hay (65%)	Hay (28%)
Corn silage (20%)	Corn silage (37%)
Grain (15%)	Grain (35%)

Soil SL Calculation for Hay



Soil SL Calculation for Corn Silage



Soil Screening Levels for Dairy Farm Scenarios

Grass-based dairy farm

SSL = 6.4 µg/kg, *dw*

"Average" Maine dairy farm

SSL = 11 µg/kg, *dw*

Estimating Soil Levels at a PFOS Milk Level

Initial average measured PFOS milk levels at Stoneridge Farms = 1.17 µg/L

(36 µg/kg dw)

1.17 µg/L

(1.03 kg/L)$^{-1}$

$$SL_{soil} = \frac{C_{milk} \times (D_{milk})^{-1}}{TF_{milk} \times \left[\left(I_{fodder} \times F_{land-f} \times F_{year-f} \times \left(TF_{plant} + MLF\right)\right) + \left(I_{soil} \times F_{land-g} \times F_{year-g}\right)\right]}$$

0.02 day/kg

13.2 kg/day

1

1

0.07

0.034

0.26 kg/day

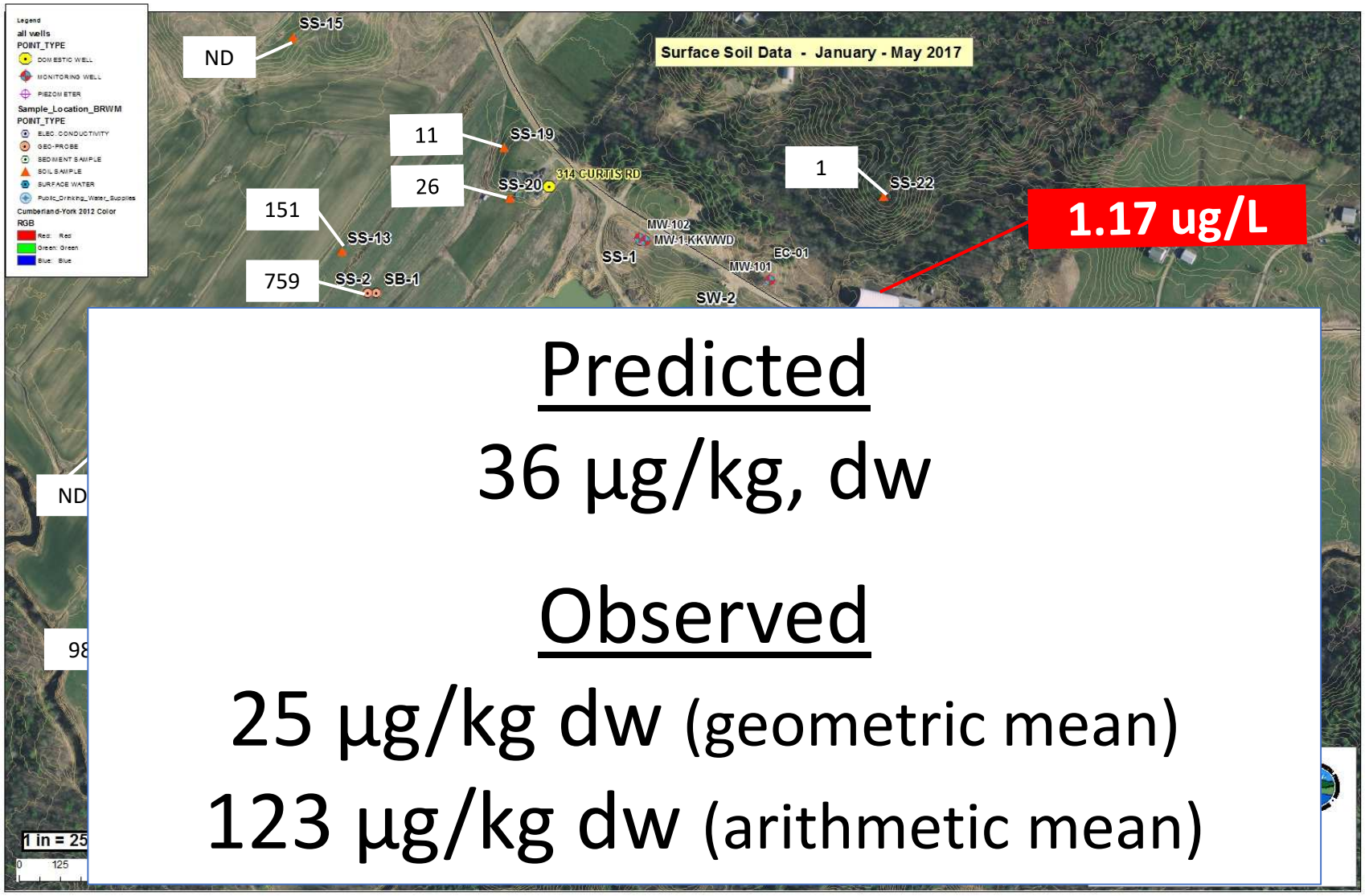
1

0.5

0.68 kg/day

0.065 kg/day

Model Checking



Predicted

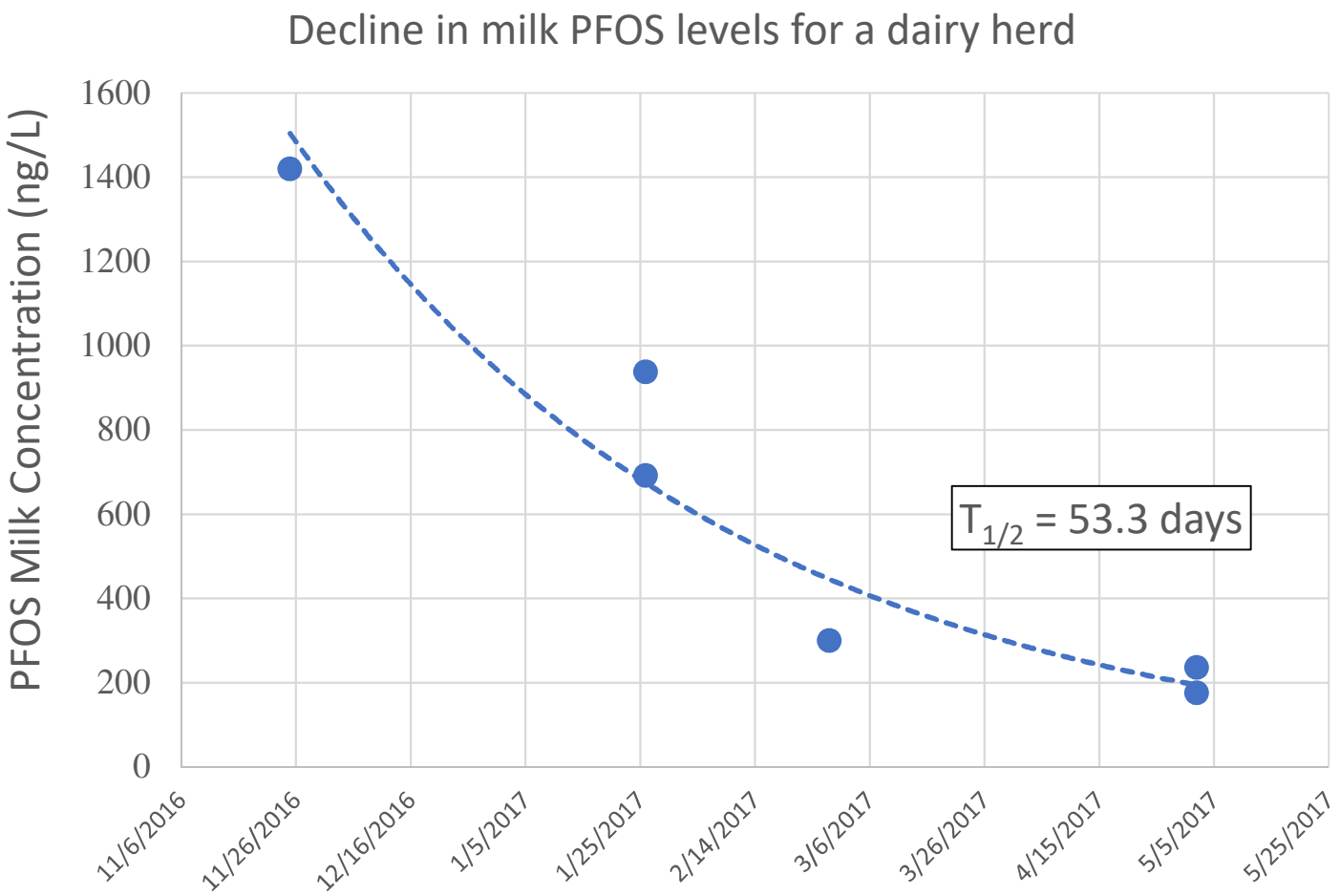
36 µg/kg, dw

Observed

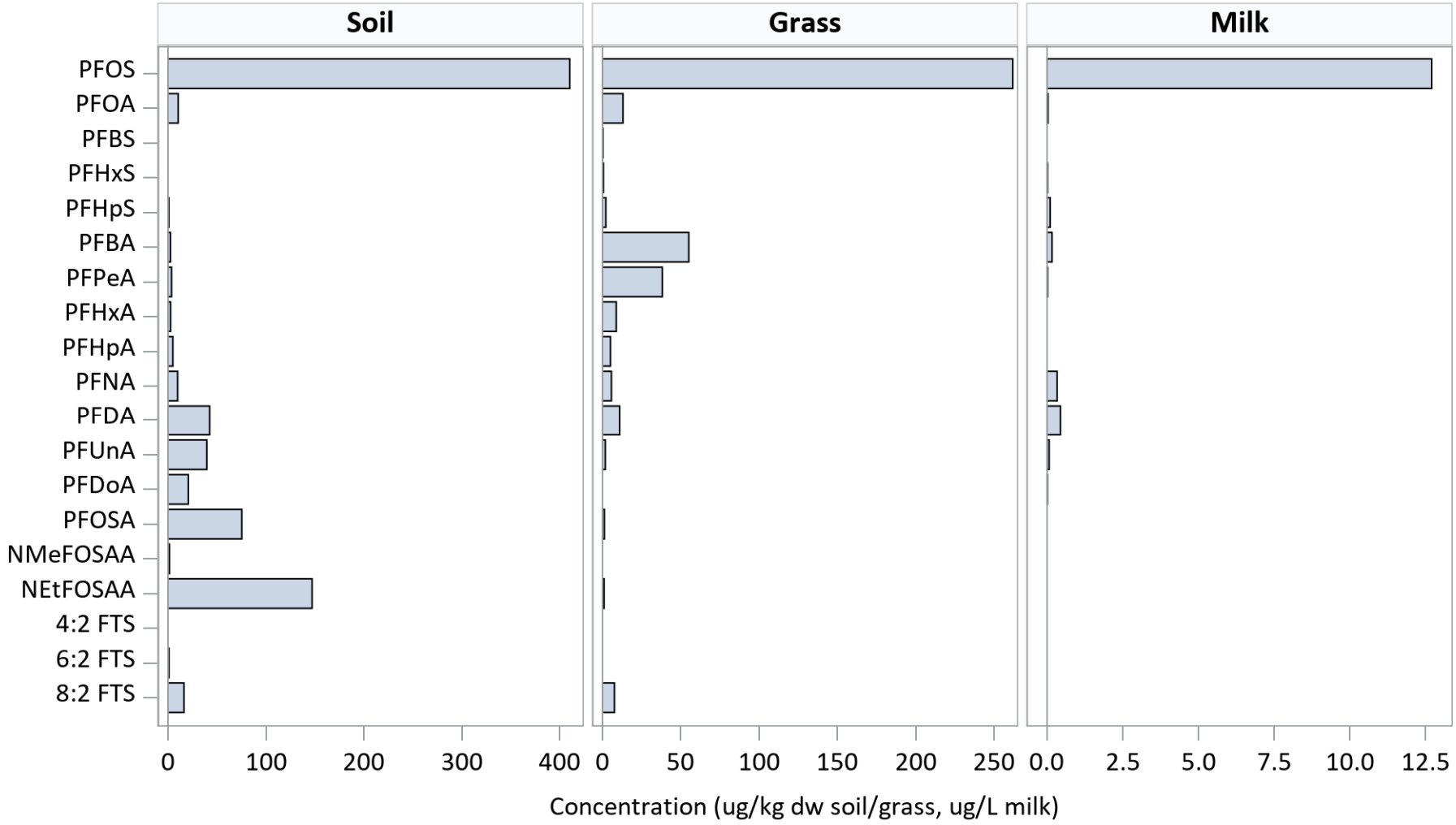
25 µg/kg dw (geometric mean)

123 µg/kg dw (arithmetic mean)

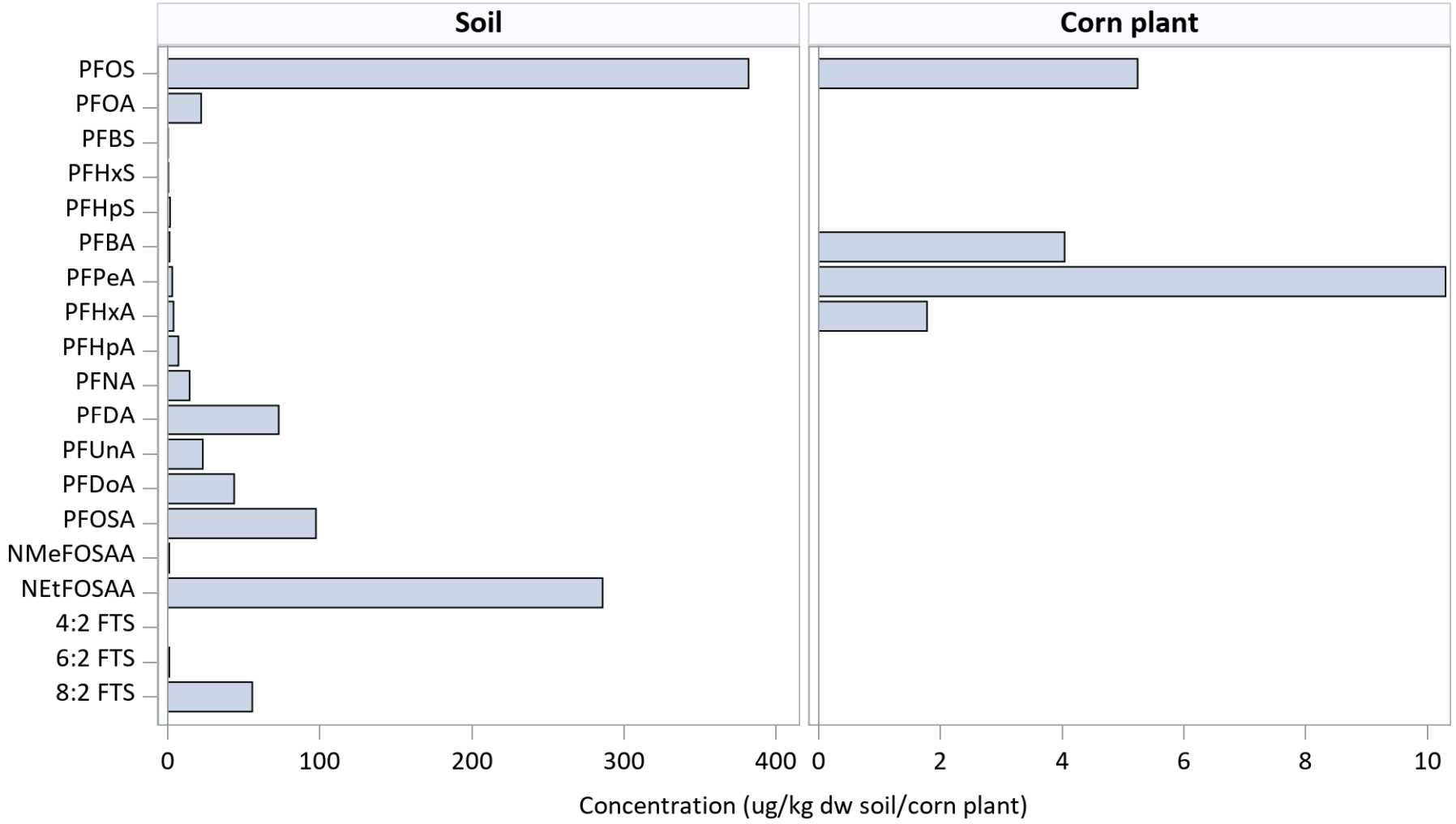
Milk PFOS Elimination Kinetics



Following Other PFAS - Soil Grass Milk



Following Other PFAS - Soil Corn Plant



Next Steps

Dairy Farm Model

- Collect more matched soil and hay/corn plant samples for PFOS analysis
- Potentially set-up multi-year controlled field plots for grass uptake studies
- Incorporate our own plant transfer factors into model
- More model checking with two additional farms with PFOS contaminated milk
- Use models for site-specific decision-making

Other agronomic models

- Beef cattle
- Pigs
- Water-to-chicken-to-egg

Acknowledgements

- Maine Department of Environmental Protection (Chris Evans et. al.) for assistance with the Maine plant uptake studies
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For More Information

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Technical Support Document for PFOS Soil Screening Levels
https://www.maine.gov/dep/spills/topics/pfas/Agronomic-Pathway-Soil-Screening-Levels-Soil-Fodder-Cows-Milk-09.16.20.pdf