

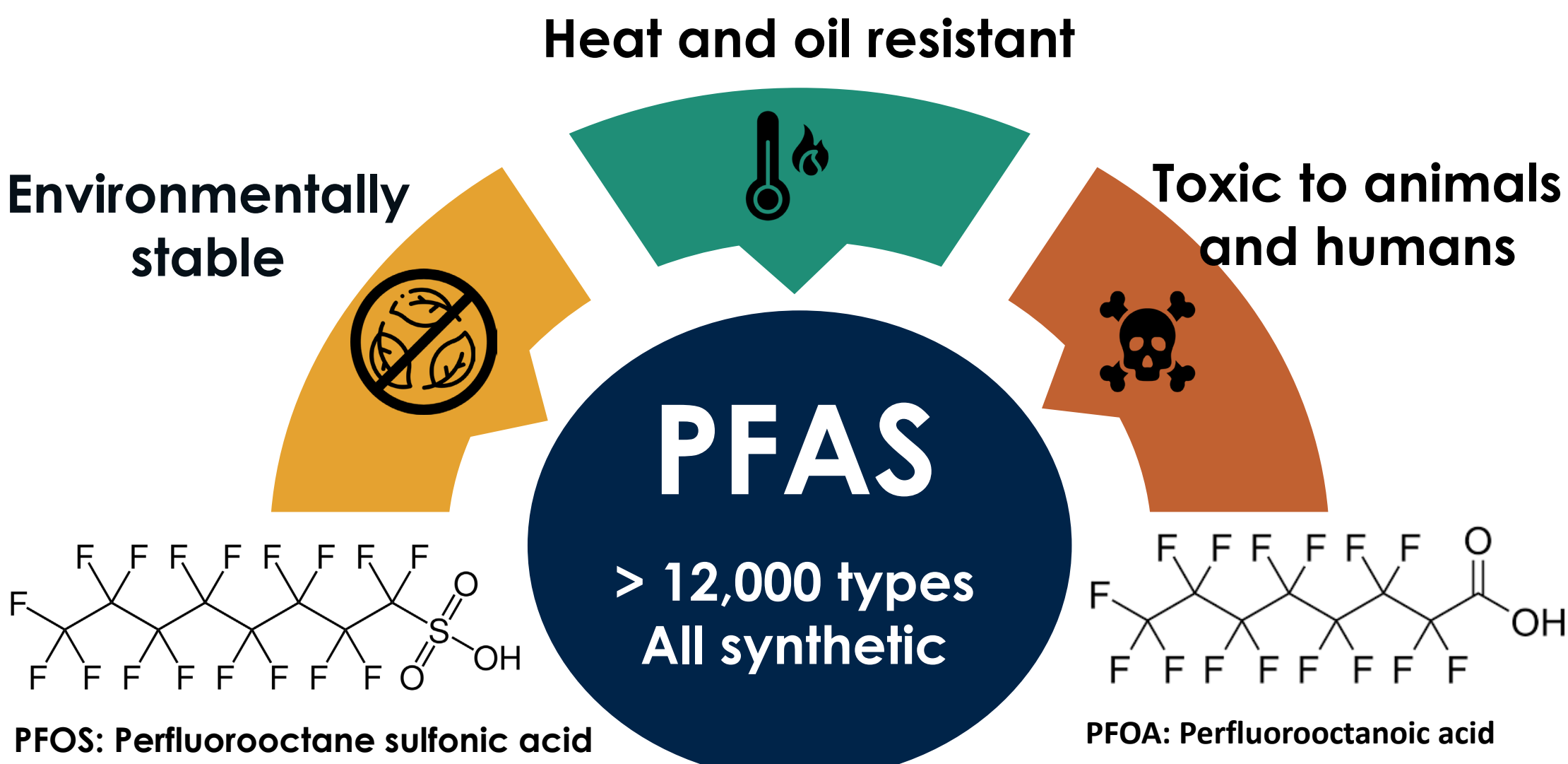


Mitigating PFAS (per- and polyfluoroalkyl substances) contamination in the conserved forage-herbivore livestock-human continuum

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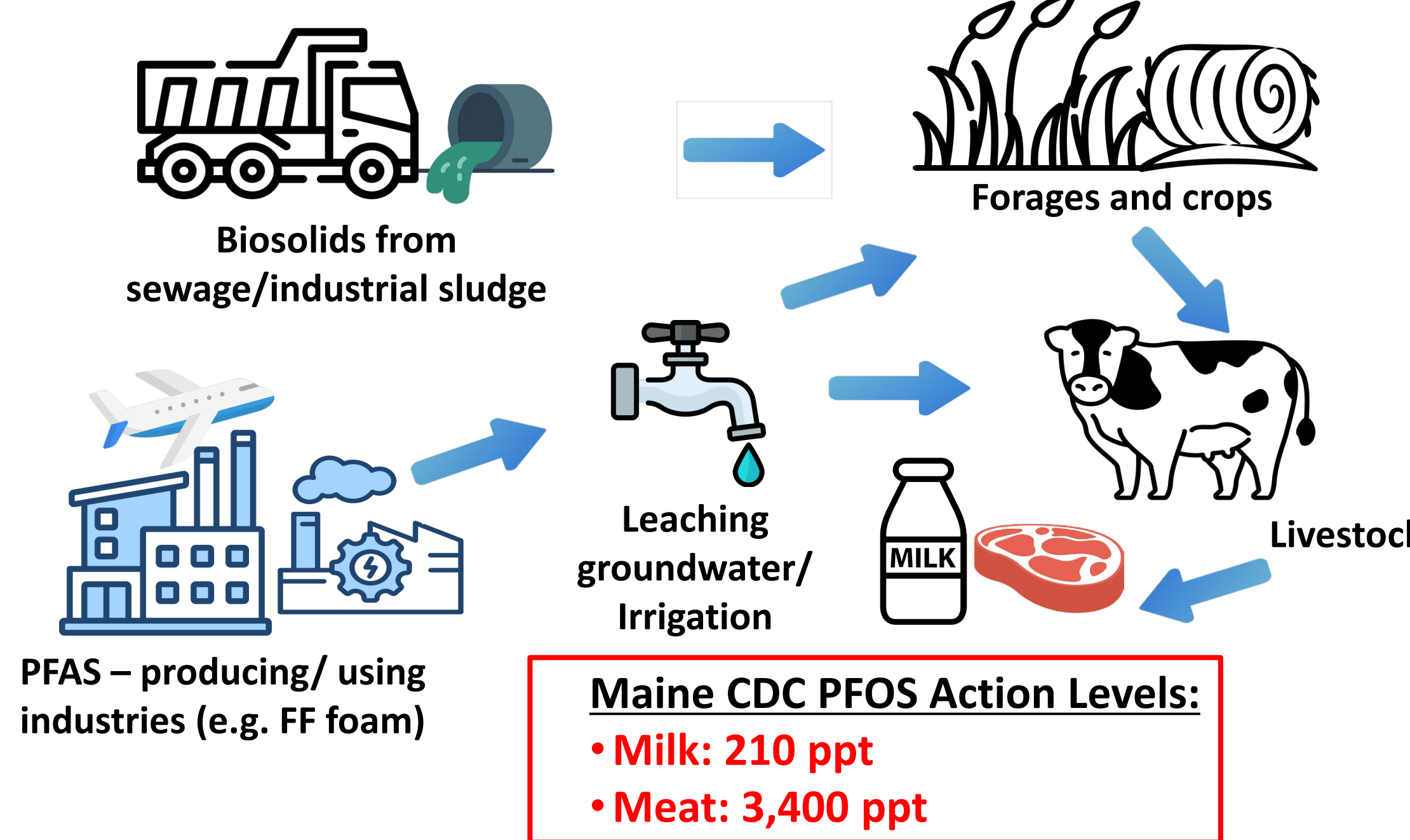


Introduction



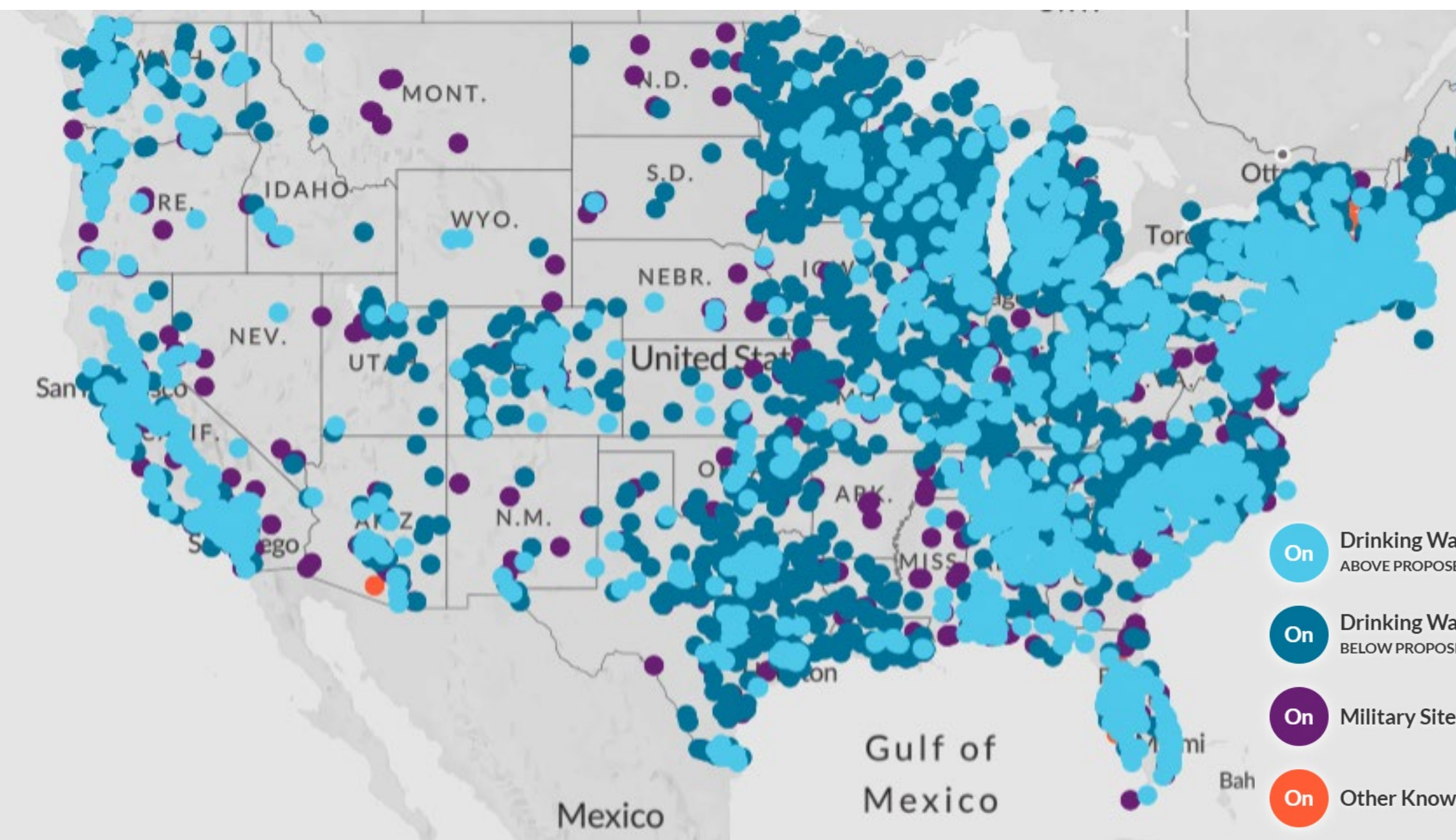
- **EPA:** Linked to decreased fertility, low birth weight, accelerated puberty, decreased immunity, reduced vaccine response, and hormonal balance disruption.
- Long chain PFAS such as PFOS have a higher tendency to bioaccumulate in animal and human tissues (Death et al., 2021).

PFAS Pathway Contamination of Livestock Products



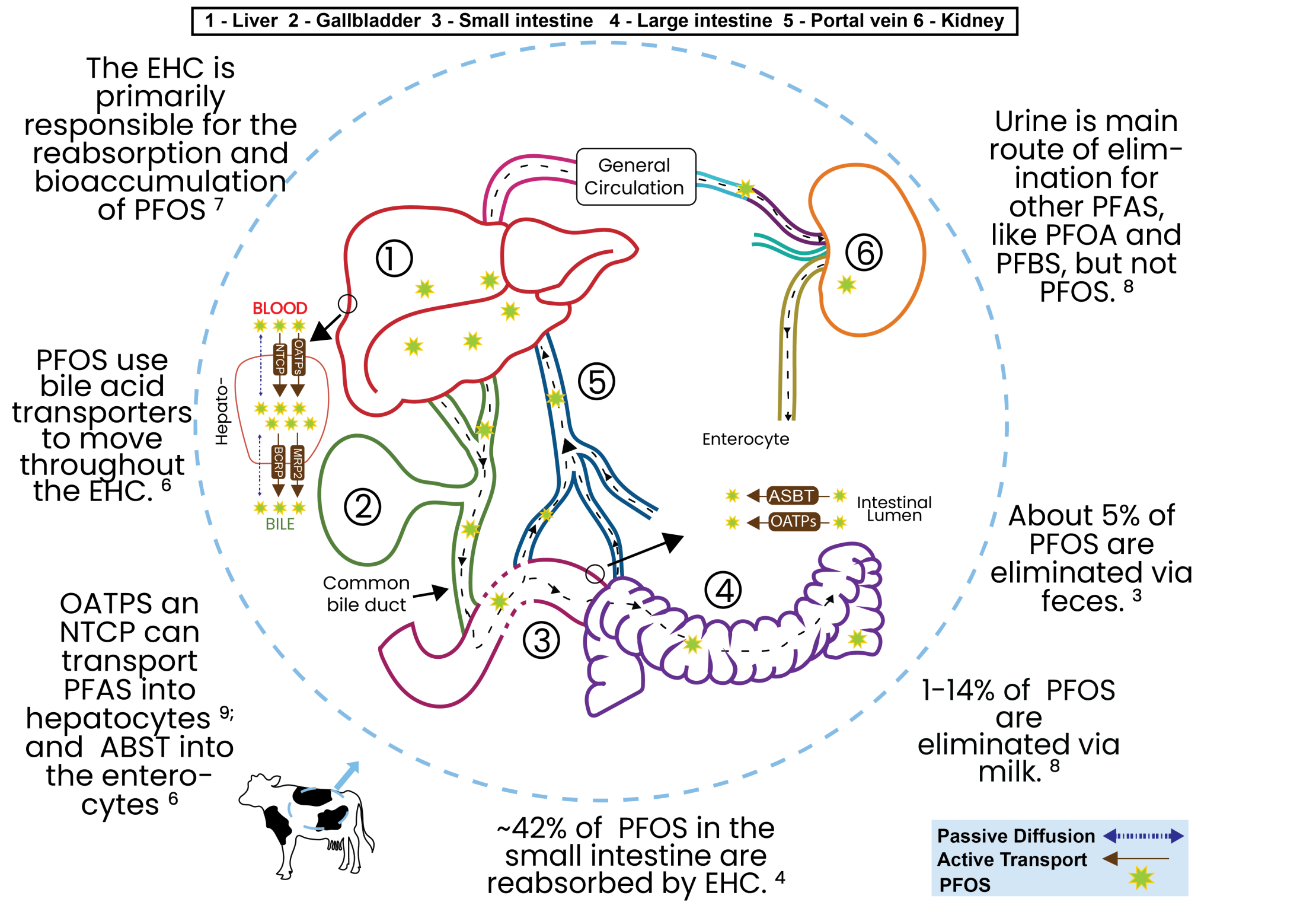
PFAS Contamination Map – EWG - Northeastern U (June 2025)

Based on EPA UCMR 5 rule – 4 ppt limit for PFOS and PFOA in drinking water

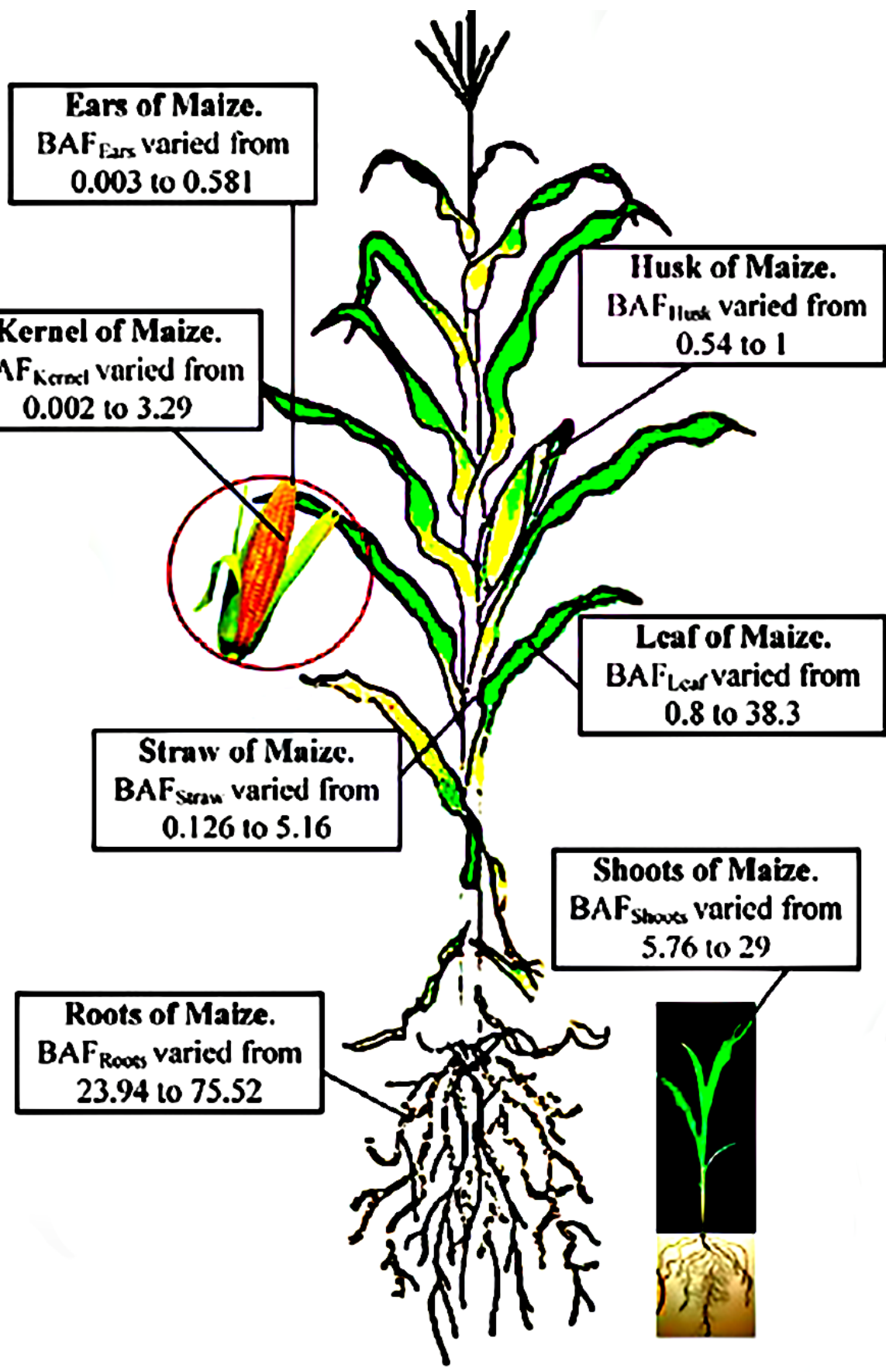


Why do PFAS bioaccumulate to different extents in contaminated animal tissues?

Enterohepatic circulation (EHC) in ruminants



Bioaccumulation factor (BAF) for PFOA and PFOS in maize different organs (Xu et al., 2022)



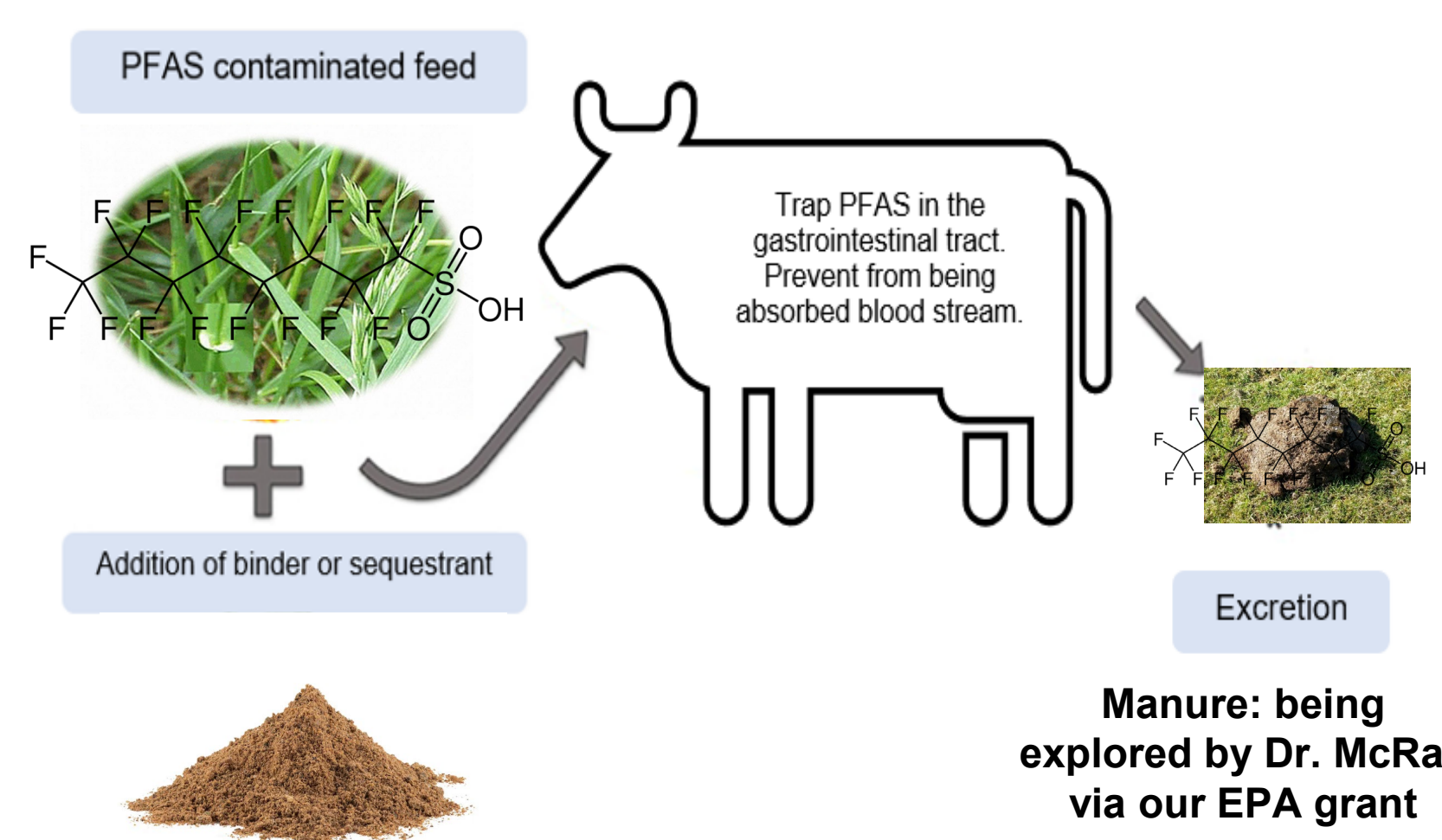
Dairy ⁶ - PFOS Crop-Specific Soil Screening Levels (ng/g dry weight)			
	Soil to Hay to Milk Screening Level	Soil to Corn-Silage to Milk Screening Level	Soil to Hay and Corn-Silage to Milk Screening Level
Grass-Based Farm	6.8	120.0	6.4
Average Maine Farm	13.8	54.8	11.0

Two scenarios:
• **Grass-based farm:** Based on EPA PRGR default intake for hay and corn silage.
• **Average Maine farm:** Based on the utilization of hay and corn silage in a typical Maine dairy farm.
These values provide the best indication of the levels that may cause concern.

- **Whole-crop corn silage has less potential to uptake PFOS and PFOA than grasses.** Corn ears have even lower levels, so **earlage production can be a viable option** (Stahl et al., 2009; Maine DACF).
- Could it be due to the high starch concentration?
- **Avoid excessive soil contamination**, as this can potentially increase PFAS concentration in the forage. The effect of mowing height is yet to be studied (Maine DACF).
- In perennial ryegrass, the **first cut had a lower PFOS and PFOA concentration relative to subsequent three cuts** (Stahl et al., 2009).

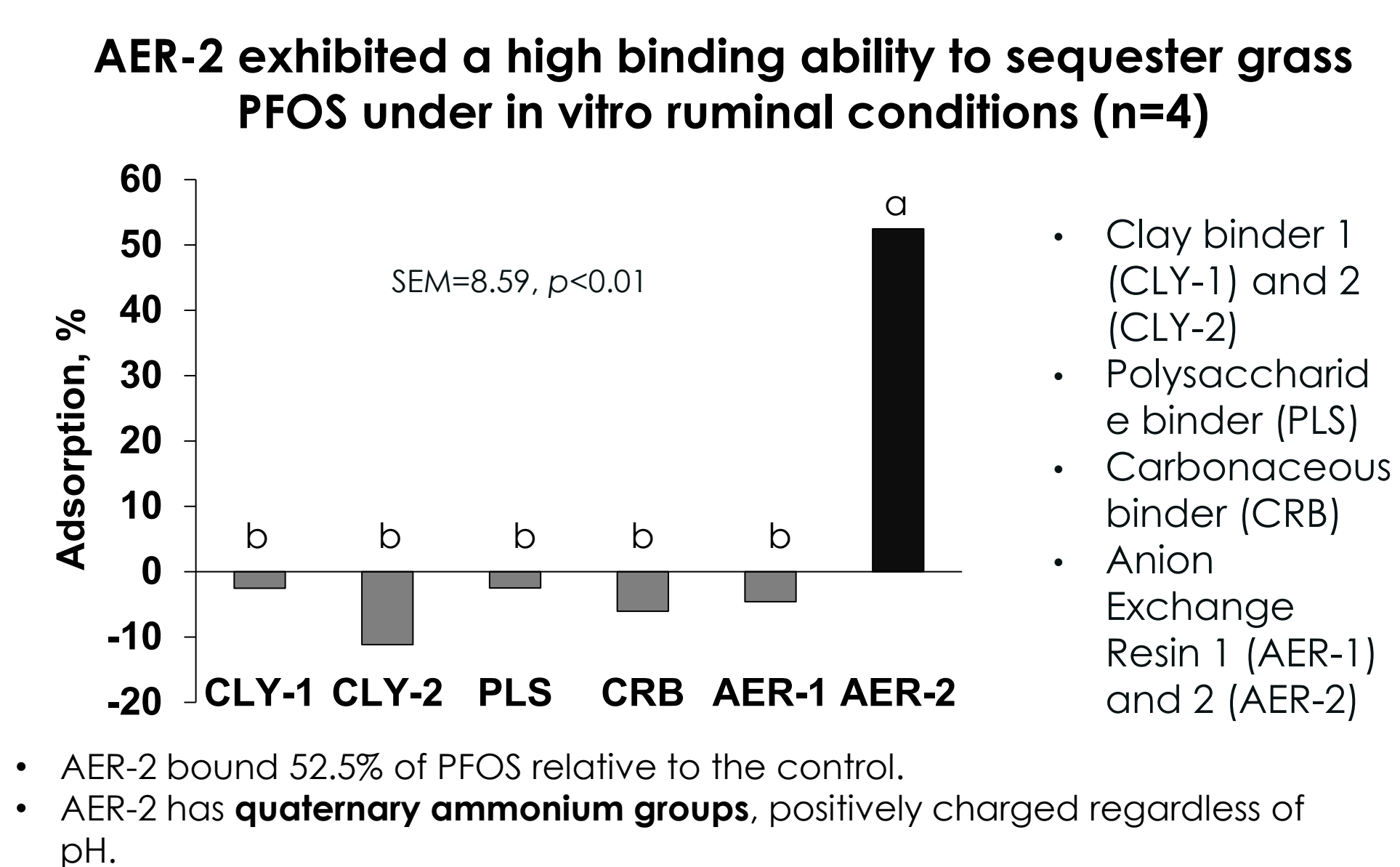
Objective

- Our research program seeks to develop strategies that can **mitigate PFAS contamination of milk and meat in affected livestock farms.**
- Our initial focus has been to identify a PFAS **feed binder** to **prevent the gastrointestinal absorption of PFAS** in livestock.
- We also analyzed all published blood animal data on PFAS.



Summary of Our Major Findings

Stage 1: Screening candidate PFAS binders



Analysis of published PFAS animal data

PFOA plasma levels (µg/mL) in In scale (ppm) in relation to exposure time (days) and PFOA exposure levels (µg/kg bw/day) across treatment groups.

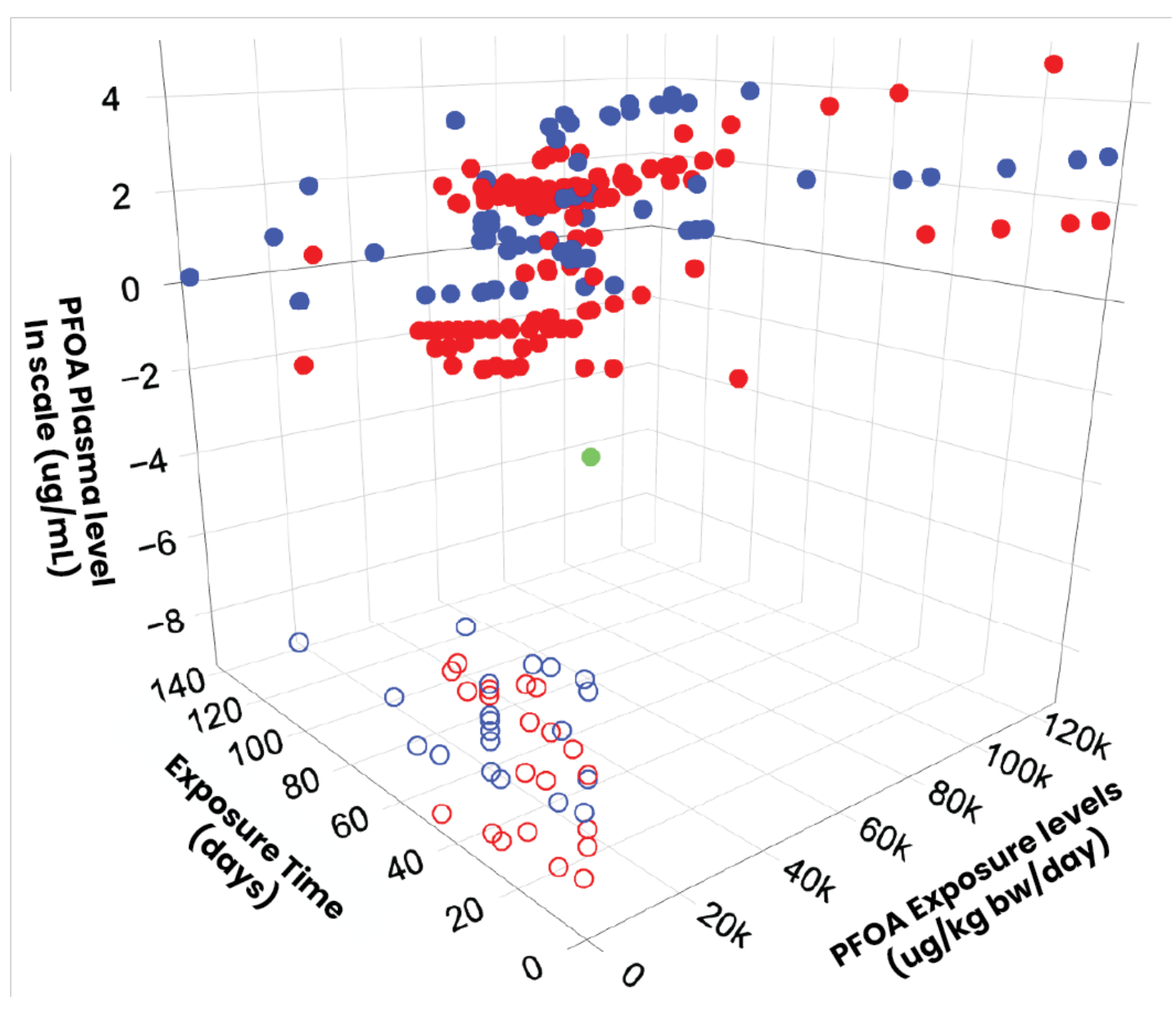


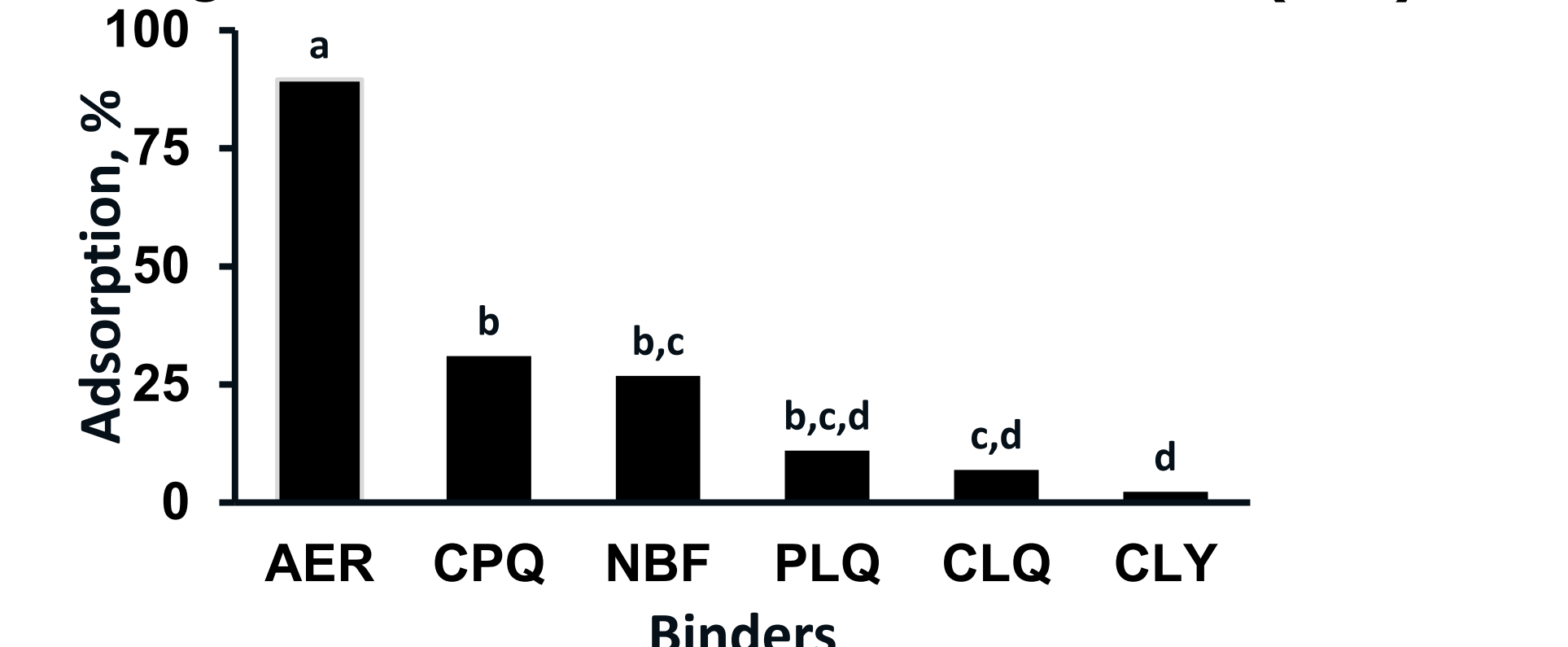
Fig. 1a: GLIMMIX model prediction

Legend:
● Castrated Male Clean Animal Exposed to PFAS
● Intact Male Clean Animal Exposed to PFAS
● Intact Female Clean Animal Exposed to PFAS
○ Castrated Male Clean Animal Not Exposed to PFAS
○ Intact Male Clean Animal Not Exposed to PFAS
○ Intact Female Clean Animal Not Exposed to PFAS

Stage 2: Screening AER-2 like binders

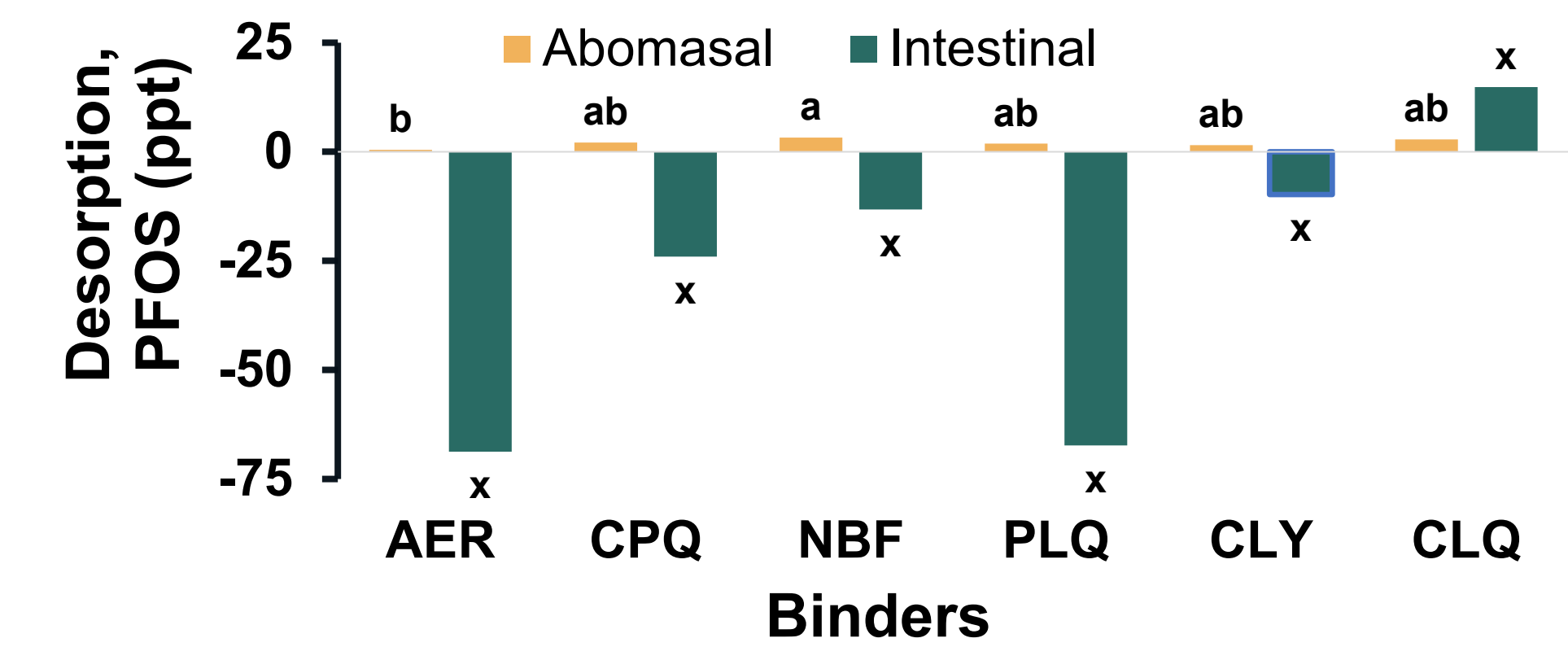
CON	Without cationic feed binder (i.e., control)
AER	Anion exchange resin
CPQ	Cationic polymer with quaternary ammonium groups
NBF	Natural by-product feed
PLQ	Polysaccharide with quaternary ammonium groups
CLQ	Clay binder amended with quaternary ammonium groups
CLY	Diocahedral phyllosilicate clay binder

AER-2 and NBF exhibited a high ability to sequester grass PFOS under ruminal conditions (n=4)



- SEM=7.56, P<0.01
- AER exhibited a high ability to sequester PFOS. In contrast, CPQ, NBF, and PLQ showed similar binding capacities.
- NBF, a low-cost natural by-product feed, reduced PFOS by 26.8% relative to the control.

Binder desorption (PFOS, ppt) under simulated abomasal and intestinal conditions (n= 4)



Abomasal: SEM= 0.99, P=0.23; Intestinal: SEM = 39.56, p=0.62

Conclusions and Implications

- After screening various types of binders, we **identified an anionic resin (AER-2) that was very effective at sequestering PFOS** (Stage 1).
- We identified that positive charges are key to sequester PFOS under rumen conditions and we screened binders with such properties, and **we identified an approved feed byproduct for ruminants** (Stage 2).
- **Limited desorption was observed under abomasal and intestinal conditions.**
- **Sex influences PFOA levels in blood**, further research is needed on this aspect.

Funding

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- Maine Organic Farmers Association
- EPA – STAR PFAS
- USDA ARS NACA Center of Excellence
- U of Maine ELH College

