Australian Government
Department of Defence
Estate and Infrastructure Group

What biota data can be adequately approximated from existing risk assessment tools for PFAS?

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Overview

1. Biota Collection
2. Intake Equations
3. Data Review
4. Measured vs Modelled Data
5. Conclusions

Biota Collection

Challenges in assessing PFAS exposure via home grown food consumption include:

- Good understanding of CSM = exposure pathway
- Diverse range
- What and how much to sample?
- Permits/ Approvals
- Cost and time

So can we approximate in the first instance?

Intake Equations

- First order kinetics can be used to approximate serum concentrations based on cumulative intake/uptake
- Use environmental media data collected during investigations- soil, water and grass concentrations combined with published consumption rates for different livestock
- Limited to PFOS, PFOA and PFHxS as limited data available for other PFAS

Estimation of Beef Cattle Serum Concentrations

$$CDI_{livestock} = \frac{\left(C_s * IngR_{l,s} + C_p * IngR_{l,p} + C_w * IngR_{l,w}\right) * CF}{BW} \quad \text{..... Equation 1}$$

$$C_{serum/plasma} = \frac{CDI_{livestock} * t_{1/2}}{0.693 * V_d} \quad \text{..... Equation 2}$$

Where:

$CDI_{livestock}$ = Chronic Daily Intake (ingestion) of plants, soil and water by livestock (mg/kg/day) (Equation 1)

$C_{serum/plasma}$ = Chemical concentration in blood serum (mg/L)

C_s = Steady state concentration in soil (mg/kg)

$t_{1/2}$ = Chemical specific serum elimination half-life (days)

$IngR_{l,s}$ = Livestock soil ingestion rate (kg/day)

V_d = Chemical specific apparent volume of distribution (L/kg)

C_p = Chemical concentration in plant tissue consumed by livestock (mg/kg)

The above equation is used under the assumption that the livestock has reached steady state.

$IngR_{l,p}$ = Livestock plant ingestion rate (kg/day)

C_w = Chemical concentration in livestock drinking water (mg/L)

$IngR_{l,w}$ = Livestock water ingestion rate (L/day)

CF = Unit conversion factor (kg/10^6 mg)

BW = Average livestock body weight (kg) at slaughter

Estimations of Egg Concentrations

PFAS Concentration in Eggs (adopted from US EPA, 2005)

$$A_{egg} = \left(\frac{\left[\sum (Fi * Qpi * Pi) + (Qs * Cs * Bs) + (Qw * Cw)\right] * (TF)}{LR * E_w}\right) \quad \text{..... Equation 1}$$

Where:

A_{egg} = Concentration of COPC in eggs (mg COPC/kg FW tissue)

Fi = Fraction of plant type (i) (grain) grown on contaminated soil and ingested by the animal (chicken) (unitless). It is assumed that the grain provided to the chicken is from a commercial source.

Qpi = Quantity of plant type (i) (grain) eaten by the animal (chicken) each day (kg DW plant/day)

Pi = Concentration of CoPC in plant type (i) (grain) eaten by the animal (chicken) (mg/kg DW)

Qs = Quantity of soil eaten by the animal (chicken) (kg/day)

Cw = Average concentration in water during exposure duration (mg/L)

Qw = Quantity of water (L)

Cs = Average soil concentration over exposure duration (mg CoPC/kg soil)

Bs = Soil bioavailability factor (unitless)

TF = Transfer factor into eggs constant (based on study by Kowalczyk 2014) chemical specific

LR = Laying Rate - Average number of eggs laid per day (based on 365 days a year and assumption that a chicken lays an egg on average 5 times a week (260 days a year))

Ew = Average weight of edible portion of egg (kg)

Estimation of Leafy Vegetable Uptake

Soil → Plants

Plant	PFOS transfer factor to edible parts (mg-chem/kg-plant per mg-chem/kg-soil)	Reference
Lettuce	0.7-2.2	Brignole et al, 2003
Corn leaf	0.8	Navarro et al, 2017
Spinach	3.82-6.0	Navarro et al, 2017
Celery	0.2	Blaine et al 2003

The following equation has been adopted to estimate uptake of per- and poly-fluoroalkyl substances (PFAS) by plants from soil.

$$C_p = C_s * CF_s \text{ .....Equation 1}$$

Where:

C_p = Concentration in plant tissue (mg/kg) – edible portion

C_s = concentration in soil (mg/kg)

CF_s = Plant concentration factor (mg-chem/kg-plant per mg-chem/kg-soil) – based on studies relevant to the edible portion of the plant (e.g. root, tuber, leaf and fruit to be evaluated separately)

Water → Plants

Plant	PFOS transfer factor to edible parts (mg-chem/kg-plant per mg-chem/L-water)	Reference
Cabbage	0.1 (edible parts)	Felizeter et al, 2014
Cabbage	3.5 (stems)	Felizeter et al, 2014
Cabbage	5 (leaves)	Felizeter et al, 2014
Cabbage	100 (root)	Felizeter et al, 2014

Where the primary source of contaminants is irrigation water, it may be a valid point of comparison to evaluate plant uptake based on concentrations in the water rather than soil. The following equation has been adopted to estimate uptake of PFAS by plants from water.

$$C_p = C_w * CF_w \text{ .....Equation 2}$$

Where:

C_p = Concentration in plant tissue (mg/kg) – edible portion

C_w = concentration in water (mg/L)

CF_w = Plant concentration factor (mg-chem/kg-plant per mg-chem/L-water) – based on studies conducted using hydroponic media relevant to the edible portion of the plant (e.g. root, tuber, leaf and fruit to be evaluated separately).

PFASIM Program Sites

Defence has commenced 27 detailed environmental investigations, 13 of which have now been completed and transitioned to management sites.

The purpose of the program is to:

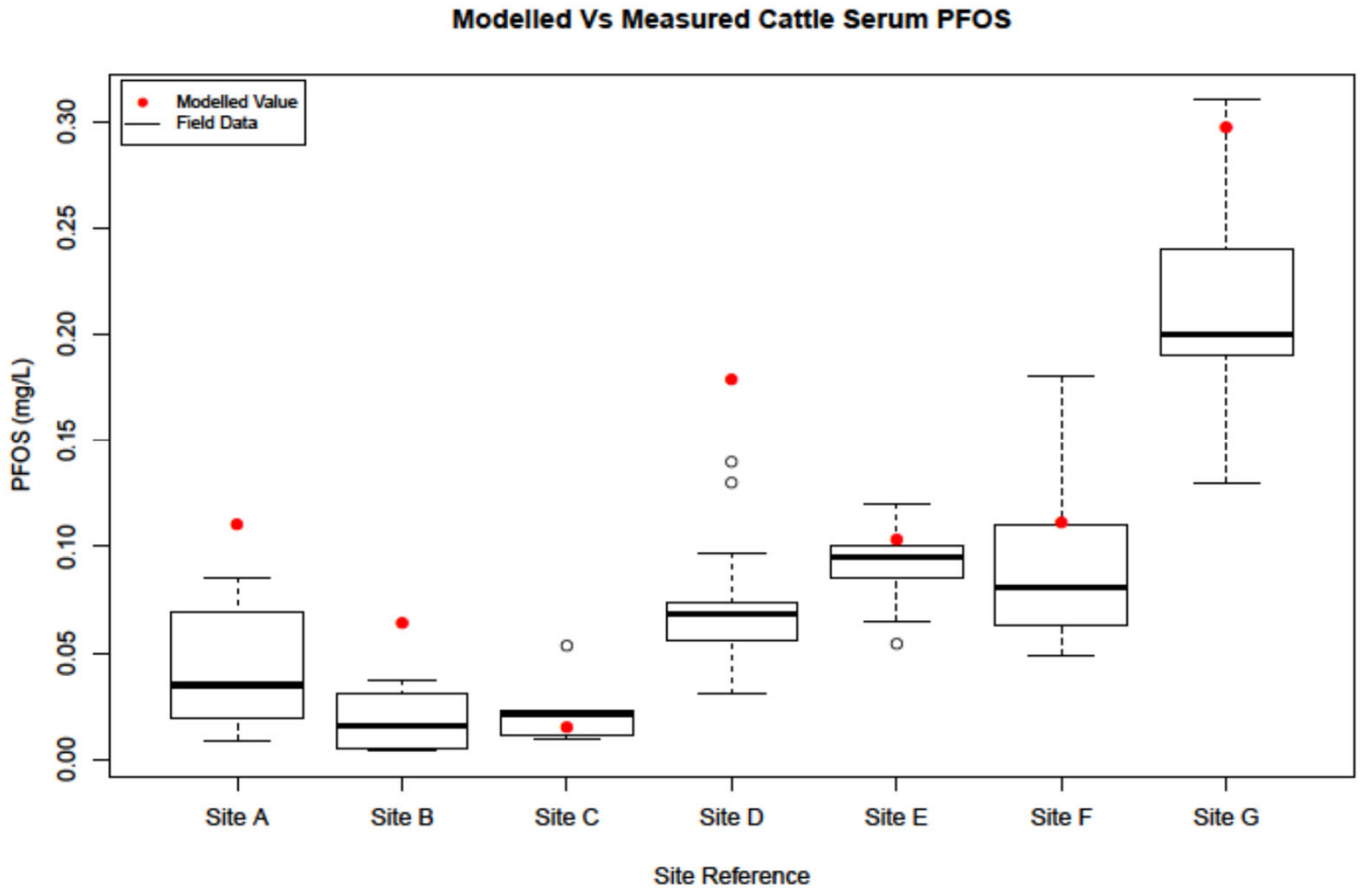
- identify the nature and extent of PFAS on and around Defence properties.
- research and implement remediation and management activities to reduce the impact of PFAS contamination.

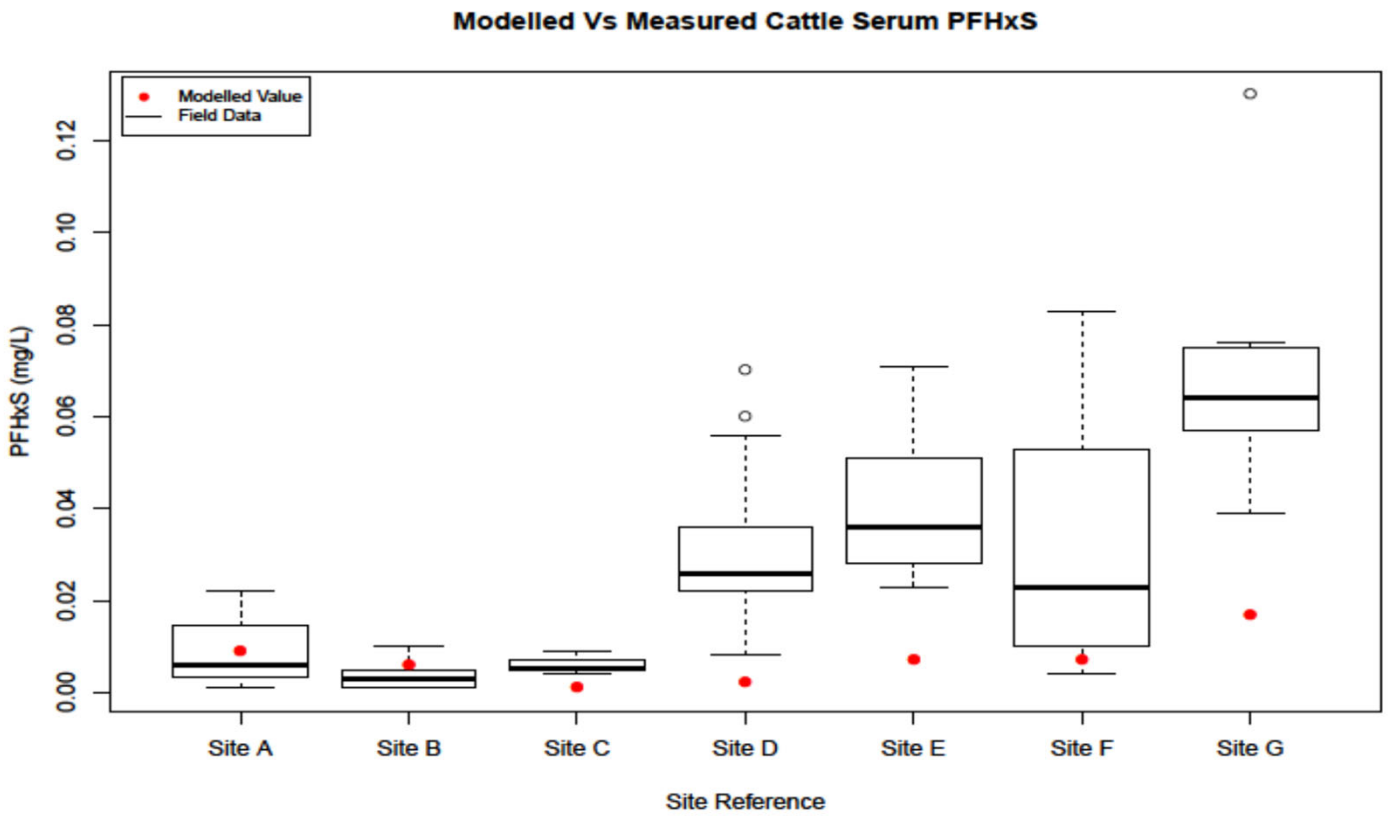
Data Review

- Looked at biota data across the Defence estate
- Diverse range of geological settings and seasons
- 3 locations were identified for review of cow serum concentrations
- 3 locations were identified for review of home grown egg concentrations
- 10 locations were identified for review of home grown fruit and vegetable concentrations

Cow Serum

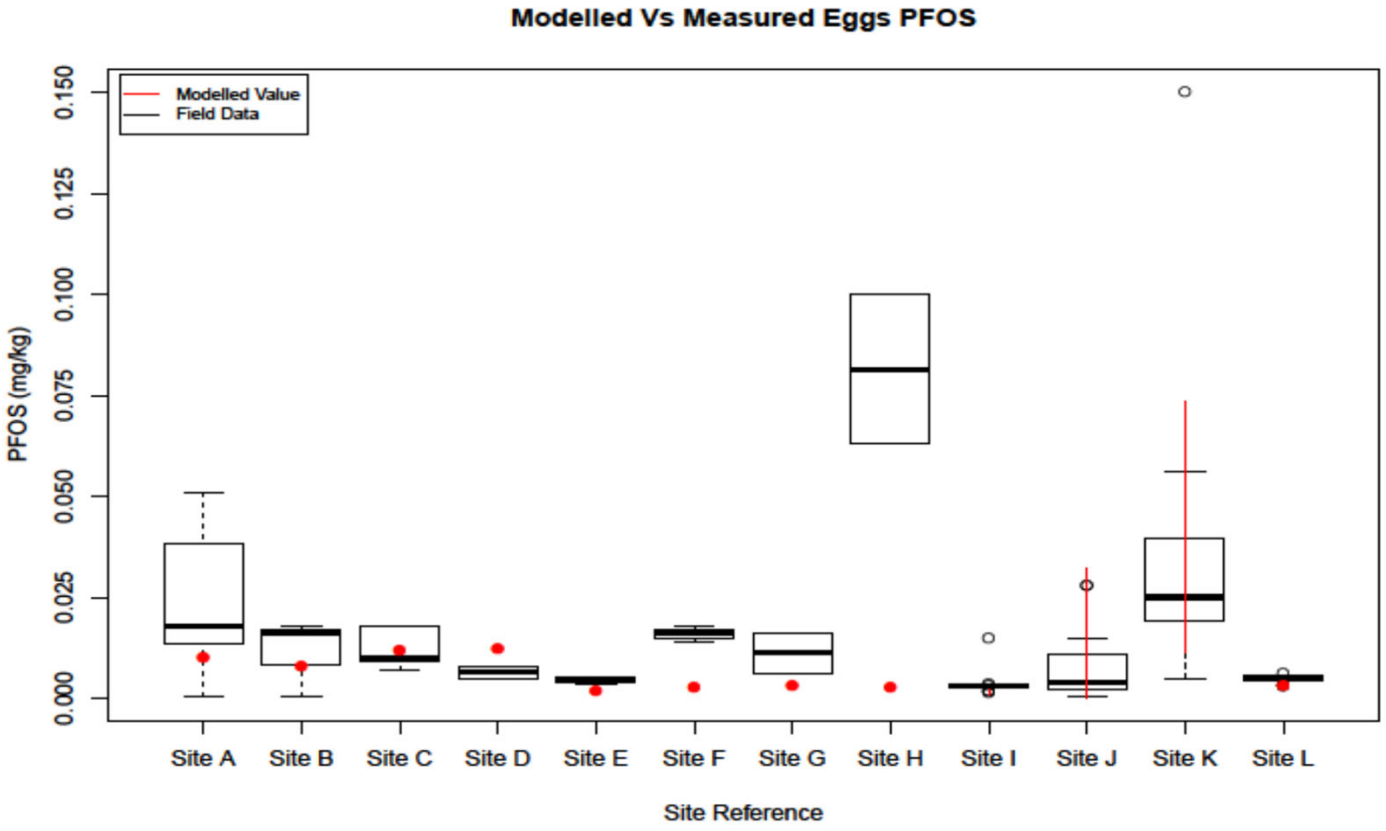
- Three locations with co-located water, soil and grass samples where cow serum was measured
- Cow serum was estimated for one site based on soil and water and with the inclusion of grazing flora for the remaining sites
- Considered PFOS and PFHxS only (limited PFOA detects due to legacy product)


Modelled Vs Measured Cattle Serum PFOS
Modelled Value
Field Data
PFOS (mg/L)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Site A
Site B
Site C
Site D
Site E
Site F
Site G
Site Reference


Modelled Vs Measured Cattle Serum PFHxS
Modelled Value
Field Data
PFHxS (mg/L)
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Site A
Site B
Site C
Site D
Site E
Site F
Site G
Site Reference

Eggs

- Estimates of Egg concentrations included soil and water only
- May be underestimated due to consumption of invertebrates (earth worms)
- Estimates of invertebrate concentration based on empirical BAF (10) values suggest even at the LOR, concentrations in earthworms would be a significant contributor
- Some outliers may be due to limitations in the soil sampling conducted


Modelled Vs Measured Eggs PFOS
Modelled Value
Field Data
PFOS (mg/kg)
0.000
0.025
0.050
0.075
0.100
0.125
0.150
Site A
Site B
Site C
Site D
Site E
Site F
Site G
Site H
Site I
Site J
Site K
Site L
Site Reference

Fruit and Vegetable Data Review

Number	Fruit	Tuber/Root/Vegetable	Leafy Vegetable	Crops (not consumed by humans)
Total	368	102	54	286
PFOS Detects?	7	6	16	68
PFHxS Detects?	2	5	17	69
Other detects?	Y(1)	Y(2)	Y(3)	Y(4)

- *Data from 10 sites was reviewed*

1. Other detects for fruit PFBS (6), PFHxA (9), PFPeA (6), PFBA (13), PFBS (5), from 4 sites typically just above or at the LOR.
2. Other detects for Tuber/Root/Vegetable PFHxA (1), PFPeA (1), PFBA (1) from 1 site typically just above or at the LOR.
3. Other detects for Leafy vegetable PFHxA (1), PFPeA (1), PFBA (1) from 1 site typically just above or at the LOR.
4. Other detects for pasture grasses and crops PFBS (8), PFOA (21), PFHxA (5), PFPeA (5), PFHpA (1) PFBA (11) from 4 sites.

Fruit and Vegetable

- Data suggests uptake by fruit and root/ tuber vegetables is limited
- Positive results were in majority from one location
- Adoption of TF for fruit and root/tuber will result in an overestimate of potential concentrations
- Some data may be influenced by not using groundwater for irrigation (i.e. sampling and exposure time isn't correlated)

Leafy Vegetables

Modelled vs measured could be estimated for one site.

Leafy Vegetable Estimated Concentration Vs Measured PFOS

Location	Modelled (mg/kg)	Measured (mg/kg)
A	0.2	0.0044
B	0.2	0.0036
C	0.2	0.0022
D	0.2	0.0025
E	0.04	0.0011

Conclusions

- Cow serum can be estimated with acceptable reliability for PFOS, other PFAS may not be as accurate
- Transfer factors are sufficiently reliable to use if it is not possible to sample eggs, provided consideration is given to the invertebrate intake.
- Data shows limited uptake into fruits, root/tuber vegetables suggesting efforts to sample should be focussed on other biota

Conclusions cont.

- Estimates of leafy vegetable concentrations are likely to be a very conservative estimate, hence sampling may be beneficial.