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Leah Smith
District and Business Support Program
Division of Waste Management
Florida Department of Environmental Protection
2600 Blair Stone Road
Tallahassee, FL 32399-2400

Re: Provisional irrigation water risk-based screening levels for PFOA and PFOS

Dear Ms. Smith:

At your request, we calculated irrigation water screening levels (IWSLs) for perfluorooctanoic acid (PFOA; CAS# 335-67-1) and perfluorooctane sulfonate (PFOS; CAS# 1763-23-1) that are protective of human health under an irrigation scenario. In the irrigation scenario, receptors are exposed to contaminated groundwater outdoors while irrigating lawns, ornamental beds, and vegetable crops. From this scenario, separate guidance levels were developed based upon: 1) exposure for residents using contaminated water for lawn and ornamental bed irrigation, including exposure from recreational use of the lawn sprinklers by children; 2) exposure for landscape maintenance workers using contaminated water for the irrigation of lawns and ornamental beds at commercial facilities; and 3) exposure for residents who use contaminated water to grow fruit and vegetables for personal consumption.

IWSLs for these chemicals are listed in Table 1 and the chemical-specific variables used for the derivation of IWSLs are listed in Table 2. Physical-chemical properties were taken from sources in order of preference used by the United States Environmental Protection Agency (USEPA) in development of their regional screening levels (RSLs). A description of the methodology used for the calculation of these IWSLs was provided in a letter dated January 14, 2009. The equations for the calculation of IWSLs are reproduced in Figure 1 and the default assumptions are provided in Table 3. Since that time, an updated version of the Exposure Factors Handbook (EFH; USEPA, 2011) was released. The homegrown produce root and shoot ingestion rates were updated using Tables 13-60 through 13-62 of the 2011 EFH. The 90th percentile consumer only ingestion rates were averaged over the ages that correspond to the exposure period, then multiplied by the body weight of the receptor of concern. The recalculated homegrown produce ingestion rates are listed in Table 4. Updated body weight and surface area values from the EFH were used in this calculation (USEPA, 2014).

For watering of lawns and ornamentals in a residential setting, the IWSLs are: 6.7 µg/L for PFOA and 72 µg/L for PFOS. In an industrial setting, where the exposed individual might be a landscape maintenance worker, the IWSLs are somewhat higher: 750 µg/L for PFOA and 370 µg/L for PFOS. Because PFOS is more volatile than PFOA (based on the estimated Henry's Law constants), PFOS results in a lower dermal exposure and higher inhalation exposure than PFOA.

Under a residential setting where dermal exposure is considered, PFOA has a lower IWSL. However, under the landscape worker scenario, only inhalation and ingestion are considered. Therefore, the increased inhalation exposure from PFOS results in a lower IWSL.

Using the Briggs model, the homegrown produce IWSL is 0.6 µg/L for PFOS. PFOA has a log Kow > 4.5. The Briggs model (Briggs, 1982), used to estimate uptake of contaminants from water into fruit and vegetables, does not produce reliable predictions for highly lipophilic chemicals with Kow values in this range. Consequently, we are unable to produce guidance levels for PFOA based on consumption of homegrown produce. From a practical standpoint, the absence of a screening value for this pathway should not be a problem. The very low water solubility limits concentrations that will be present in water for plant uptake. It is important to note that the produce IWSLs are very conservative screening values. Exceedance of the IWSL does not necessarily mean that contaminant levels in produce are a concern for human health. If the IWSL is exceeded, we recommend sampling produce to determine actual exposure concentrations.

It is important to point out that these IWSLs are based upon oral reference doses for PFOA and PFOS developed by the USEPA in 2016 as part of their effort to create drinking water health advisories for these substances (USEPA 2016a; USEPA 2016b). Reference doses for PFOA and PFOS are based upon critical studies showing adverse effects on development in mice and rats, respectively. Recently, concern has been expressed that these reference doses are not sufficiently protective, and that immunotoxicity may be a more sensitive endpoint, particularly for PFOS (see, for example, Lilienthal et al. 2017). In the short time since the USEPA health advisories were developed, several epidemiological studies have been published showing an association between PFOA and/or PFOS serum concentrations and one or more indicators of adverse effects on the immune system, providing impetus for stronger consideration of immunotoxicity when developing safe limits for PFOA and PFOS exposure. We note that the draft *Toxicological Profile for Perfluoroalkyls* recently released for public comment by the Agency for Toxic Substances and Disease Registry (ATSDR) develops a Minimal Risk Level (MRL) for PFOS based upon developmental toxicity, but divides the point of departure by an additional factor of 10 based upon concern that an MRL based on developmental toxicity alone may not be protective of adverse immune system effects. The resulting MRL (2E-06 mg/kg/day) is an order of magnitude lower than the USEPA PFOS reference dose (2E-05 mg/kg/day). For PFOA, the ATSDR considers an MRL based upon developmental toxicity to also be protective of immunotoxicity, but selection of a different critical study (with a different point of departure), along with different derivation of the human equivalent dose, also resulted in an MRL (3E-06 mg/kg/day) an order of magnitude lower than the USEPA reference dose (2E-05 mg/kg/day). Based upon these and other concerns, several states have adopted drinking water criteria for PFOA and/or PFOS that are lower than the USEPA health advisories, including Michigan, Minnesota, New Jersey, and Vermont.

Given uncertainty regarding the safe dose limit for PFOA and PFOS discussed above, the IWSLs developed here should be considered provisional and re-evaluated at appropriate intervals as new information on PFOA and PFOS toxicity and risk is published.

Please let us know if you have any questions regarding these calculations.

Sincerely,

Leah D. Stuchal, Ph.D.

Stephen M. Roberts, Ph.D.

References:

Briggs, G.G., Bromilow, R.H., and Evans, A.A. (1982) Relationships between lipophilicity and root uptake and translocation of non-ionised chemicals by barley. *Pestic. Sci.* 13, 495-504.

Lilienthal H, Dieter HH, Holzer J, Wilhelm M (2017). Recent experimental results of effects of perfluoroalkyl substances in laboratory animals — relation to current regulations and guidance. *Int. J. Hyg. Environ. Health* 220:765-775.

USEPA (2011) *Exposure Factors Handbook: 2011 Edition*. United States Environmental Protection Agency, National Center for Environmental Assessment, Office of Research and Development, Washington, DC.

USEPA (2014) *Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, OSWER Directive 9200.1-200*. United States Environmental Protection Agency, Office of Solid Waste and Emergency Response, Washington, D.C.

USEPA (2016a) *Drinking Water Health Advisory for Perfluorooctanoic Acid (PFOA*). United States Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (2016b) *Drinking Water Health Advisory for Perfluorooctane Sulfonate (PFOS)*. United States Environmental Protection Agency, Office of Water, Washington, DC.

USEPA (2018) *Regional Screening Levels (RSLs) – User's Guide*. United States Environmental Protection Agency. https://www.epa.gov/risk/regional-screening-levels-rsls-users-guide#supporting Accessed: June 11, 2018.

Table 1 – Irrigation water risk-based guidance levels for PFOA and PFOS

Chemical	Residential IWSL (µg/L)	Industrial IWSL (µg/L)	Produce IWSL (µg/L)
PFOA	6.7	750	NA
PFOS	72	370	0.6

NA - Not applicable. The Briggs plant uptake model is not applicable to chemicals with a log Kow>4.5.

Table 2 – Chemical-specific variables for PFOA and PFOS

Chemical-Specific Variable	PFOA		PFOS	
	Value	Source	Value	Source
RfD_o	2E-05 mg/kg-d	USEPA 2016a	2E-05 mg/kg-d	USEPA 2016b
RfD_d	2E-05 mg/kg-d	extrapolated	2E-05 mg/kg-d	extrapolated
RfD_i	2E-05 mg/kg-d	extrapolated	2E-05 mg/kg-d	extrapolated
log K_{ow}	6.3	PYSPROP	4.49	EPIWIN estimate
K_{oc}	4370 L/kg	EPIWIN K_{ow} estimation method	2562 L/kg	EPIWIN K_{ow} estimation method
Henry's Law constant	3.01E-05 atm-m^3/mol	PHYSPROP estimated value	0.011 atm-m^3/mol	EPIWIN bond-estimated value
K_p	0.114 cm/hr	EPIWIN estimate	0.00236 cm/hr	EPIWIN estimate

PHYSPROP – Physical Properties Database by Syracuse Research Corporation
EPIWIN – Estimation Programs Interface for Windows v4.1.1

Figure 1 – IWSL equations for non-carcinogens

Equation for the calculation of an IWSL for PFOA and PFOS:

$$IWSL = \frac{THI \times AT_{nc}}{\left[\left(\frac{EF_i \times IR_o \times ED_c}{BW_c \times RfD_o}\right) + \left(\frac{EF_i \times SA \times T_t \times K_p \times \left(1 - \frac{SE}{100}\right) \times CF \times ED_c}{BW_c \times RfD_d}\right) + \left(\frac{EF_i \times IR_{ic} \times T_t \times V_w \times \frac{SE}{100} \times ED_c}{BW_c \times V_a \times RfD_i}\right)\right]}$$

Equation for the calculation of a commercial/industrial IWSL for PFOA and PFOS:

$$IWSL = \frac{THI \times AT_{nc}}{\left[\left(\frac{EF_i \times IR_o \times ED_w}{BW_w \times RfD_o}\right) + \left(\frac{EF_i \times IR_{iw} \times T_t \times V_w \times \frac{SE}{100} \times ED_w}{BW_w \times V_a \times RfD_i}\right)\right]}$$

Calculation of an IWSL for the consumption of homegrown produce for PFOA and PFOS:

$$IWSL = \frac{THI \times AT_{nc}}{\left(\frac{EF_v \times [(RCF \times Ir_{rc}) + (SCF \times Ir_{sc})] \times \left(1 - \frac{SE}{100}\right) \times RD \times ED_c}{BW_c \times RfD_o}\right)}$$

Supporting equations:

$$SE = [7.95 \times ln(H)] + 68.17$$

$$RCF = 10^{0.77logK_{ow}-1.52} + 0.82$$

$$SCF = (10^{0.95logK_{ow}-2.05} + 0.82)\left(0.784 \times 10^{-0.434(logK_{ow}-1.78)^2/2.44}\right)$$

Table 3 – Default assumptions used in the calculation of IWSLs for PFOA and PFOS

Abbreviation	Definition	Value
AT_{nc}	Non-carcinogenic averaging time	(365 x ED) d
BW_w	Worker body weight	80 kg
BW_c	Child body weight	15 kg
CF	Correction factor	0.001 L/cm^3
ED_w	Worker exposure duration	25 y
ED_c	Child exposure duration	6 y
EF_i	Irrigation exposure frequency	52 d/y
EF_v	Vegetable exposure frequency	350 d/y
H	Dimensionless Henry's Law constant	chemical-specific
IWSL	Irrigation water screening level	(mg/L)
IR_{ic}	Child inhalation rate	1.2 m^3/h
IR_{iw}	Worker inhalation rate	1.5 m^3/h
IR_o	Water incidental ingestion rate	0.01 L/d
Ir_{rc}	Child ingestion of root vegetables	0.024 kg/d
Ir_{sc}	Child ingestion of shoot vegetables	0.131 kg/d
K_{oc}	Octanol-carbon partition coefficient	chemical specific (L/kg)
K_{ow}	Octanol-water partition coefficient	chemical-specific
K_p	Permeability coefficient	chemical-specific (cm/h)
RCF	Root concentration factor	chemical-specific (L/kg)
RD	Rainfall dilution	0.5
RfD_d	Dermal reference dose	chemical-specific (mg/kg-d)
RfD_i	Inhalation reference Dose	chemical-specific (mg/kg-d)
RfD_o	Oral reference dose	chemical-specific (mg/kg-d)
SA	Child surface area	6378 cm^2
SCF	Shoot concentration factor	chemical-specific (L/kg)
SE	Water-to-air chemical stripping efficiency	chemical-specific
THI	Target hazard index	1
TR	Target cancer risk	1.00E-06
T_t	Irrigation time	0.483 h/d
V_a	Volume of air for volatilization	31320 m^3
V_w	Volume of water used	1450 L

Table 4 – Updated homegrown produce ingestion rate (IR) assumptions based on the 2011 Exposure Factors Handbook

Receptor	IRroot (g/d)	IRshoot (g/d)
Child	0.024	0.131
Aggregate Resident	0.066	0.281