

Free-range eggs dioxin contamination assessment: comparison between a simple model and *in situ* measurements to determine a maximum egg frequency consumption

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Background and Objectives

The PCDD/Fs are classified as persistent organic pollutants (POPs) and bioaccumulate in fat rich tissue along the food chain.
-> Food of animal origin is the main environmental source of human exposure to PCDD/Fs.

In 2020, a high soil contamination of dioxins and furans (PCDD/Fs) was discovered in Lausanne (Switzerland). The source of this contamination was a former waste incinerator.

A health risk assessment confirmed the most significant exposure scenarios for ingestion[1]:
- **Free-range eggs** - Children in play ground - Curcubits cultivation

The consumption of eggs from free-range laying hens raised on contaminated soil is supposed to be one of the highest risk of PCDD/Fs exposure.

The objectives:

- to simulate the expected PCDD/F concentrations in eggs as a function of the PCDD/F concentrations in soil using an existing animal toxicokinetic model
- to recommend a maximal egg frequency consumption in humans so as not exceed the tolerable daily intake.

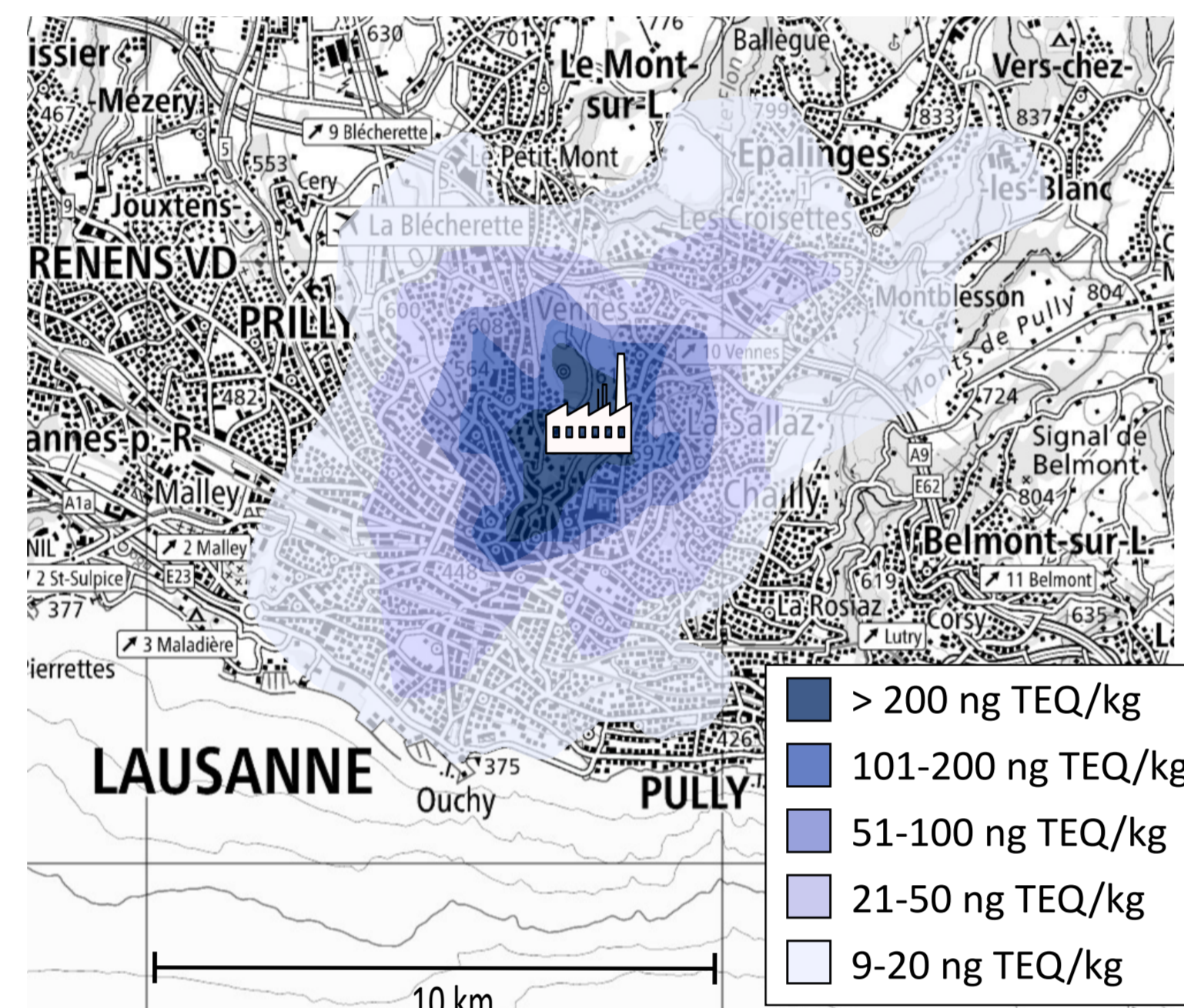


Figure 1: map of the PCDD/F contamination in Lausanne (Switzerland) accessible online: geo.vd.ch

Model

Outdoor runs favor hen's innate behavior to seek for their feed, leading to ingestion of relevant amounts of soil. The PCDD/Fs absorbed from soil are further accumulated into their body fat and eliminated through the eggs' yolk. A laying hen physiologically-based toxicokinetic (PBTK) model for PCDD/Fs was adapted to evaluate the sensitivity of the different parameters for local data focusing on soil PCDD/Fs concentration and hen's intake level. [2]

The daily dose (D) is defined as a function (3) of the soil concentration (C_{soil}), the bioaccessibility (B) and the mass of soil ingested (S_{uptake}).

Related equations to the PBPK model:

$$\frac{dA_c}{dt} = F_{abs} * D - (q_c + \epsilon_y + k) * A_c + q_f * A_f \quad (1)$$

$$\frac{dA_f}{dt} = q_c * A_c - q_f * A_f \quad (2)$$

$$\text{Daily dose} = D = C_{soil} * S_{uptake} * B \quad (3)$$

where

F_{abs} : the absorbed fraction

A_c, A_f : the amounts in the central and fat compartments

q_c, q_f : the flux rate from the central compartment to the fat compartment (and inversely)

ϵ_y, k : the flux of excretion in the eggs' yolk and the metabolic clearance

Table 1: Entry parameters of the model

Acronyme	Description	Units	Value
EXPOSITION			
C_{soil}	Soil PCDD/Fs concentration	ng TEQ/kg soil	Variable
B	Biodisponibilité	-	0.5 [2]
S_{uptake}	Ingested soil mass per day	g soil/day	5-30 [3]
$T_{exposure}$	Exposure duration	days	Variable
$T_{postexp}$	Time after the exposure	days	Variable
T_{egg}	Delay between egg-laying and the first exposure	days	Variable
PHYSICAL FEATURES			
M_{feed}	Ingested feed mass	kg dry matter/day	0.113 [2]
F_{abs}	Absorbed fraction	-	0.885 [2]
FLUX			
ϵ_y	Elimination rate via egg's yolk	-/day	0.0485 [2]
k	Clearance elimination rate	-/day	0.0056 [2]
q_c	PCDD/Fs transfert for A_c to A_f	-/day	0.168 [2]
q_f	PCDD/Fs transfert for A_f to A_c	-/day	0.0776 [2]

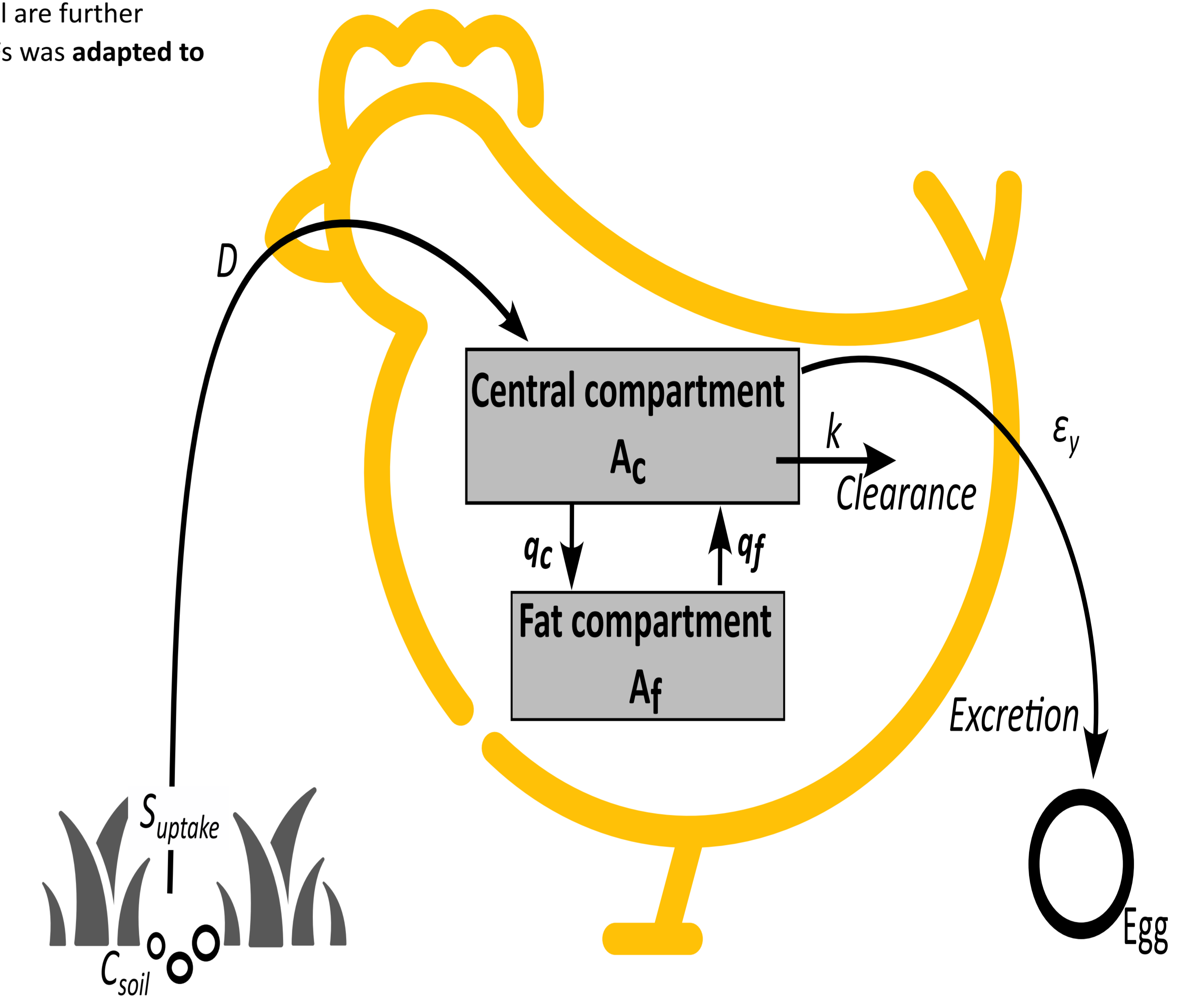


Figure 2: two compartments PBPK model for the distribution of PCDD/Fs in laying hens. [2]

Results

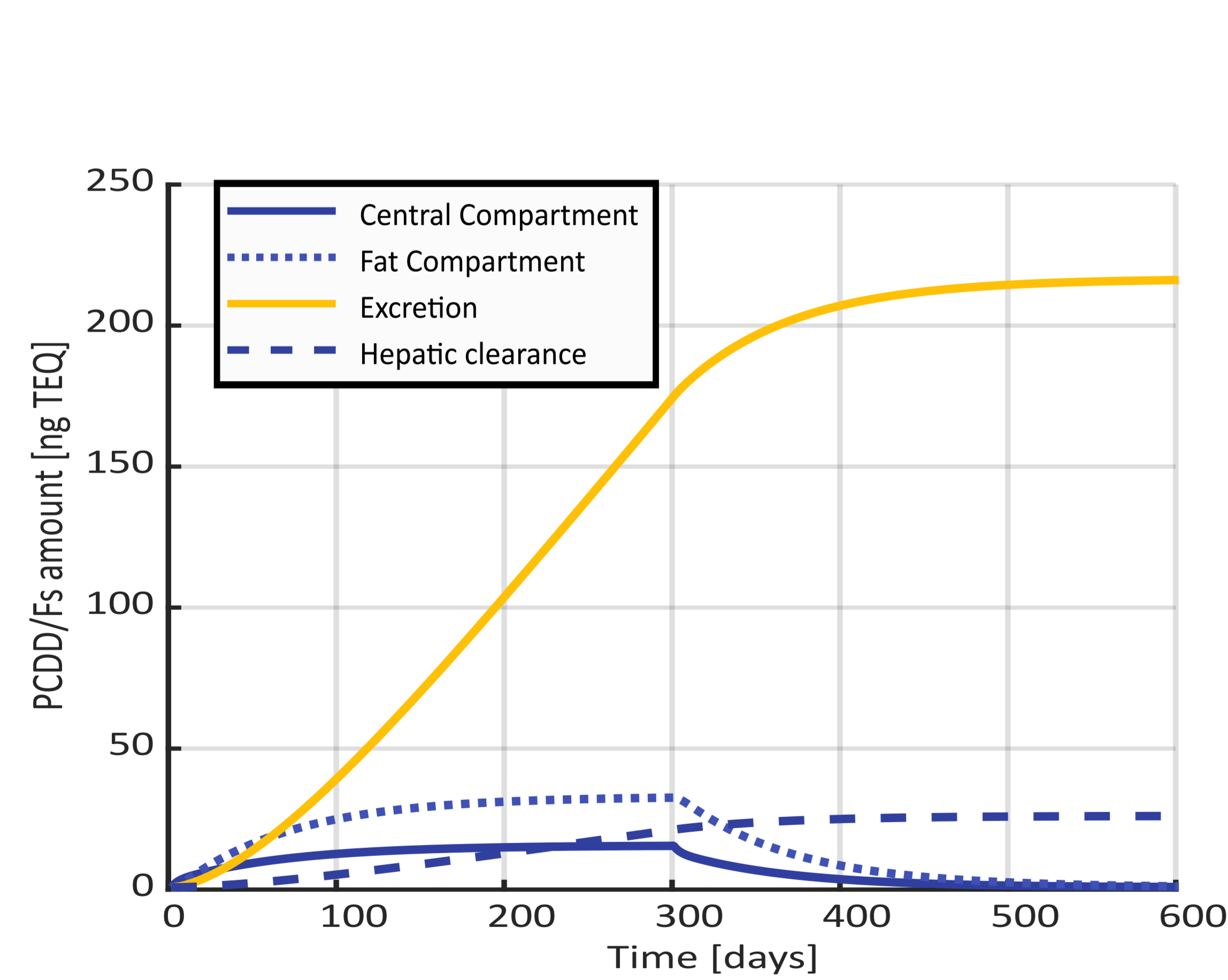


Figure 3: Amount of PCDD/Fs in the different compartment of a hen exposed to a soil of 100 [ng TEQ/kg soil] during 300 days (followed by 300 days without exposure). The excretion curve (in yellow) is cumulative.

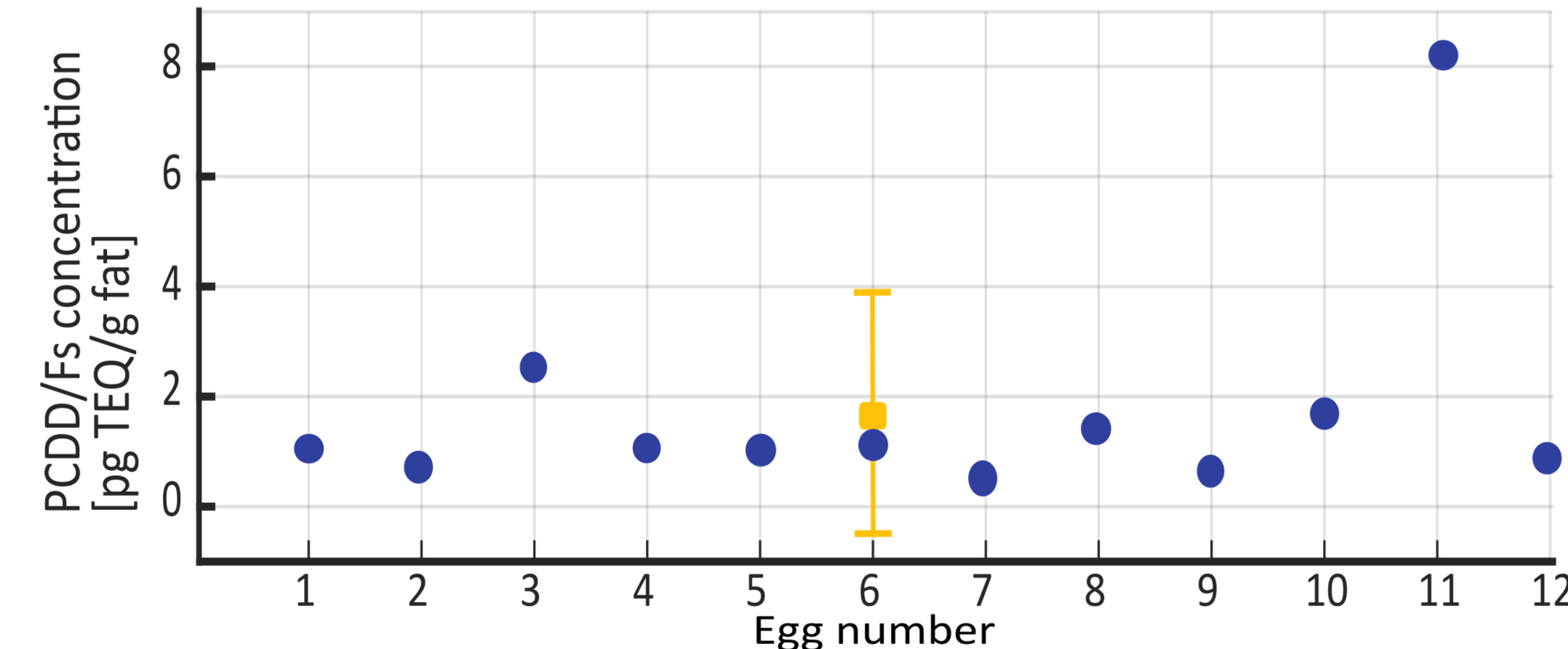


Figure 4: Variability of the measured concentration in 12 eggs produced in the same farm, with the average and the standard deviation

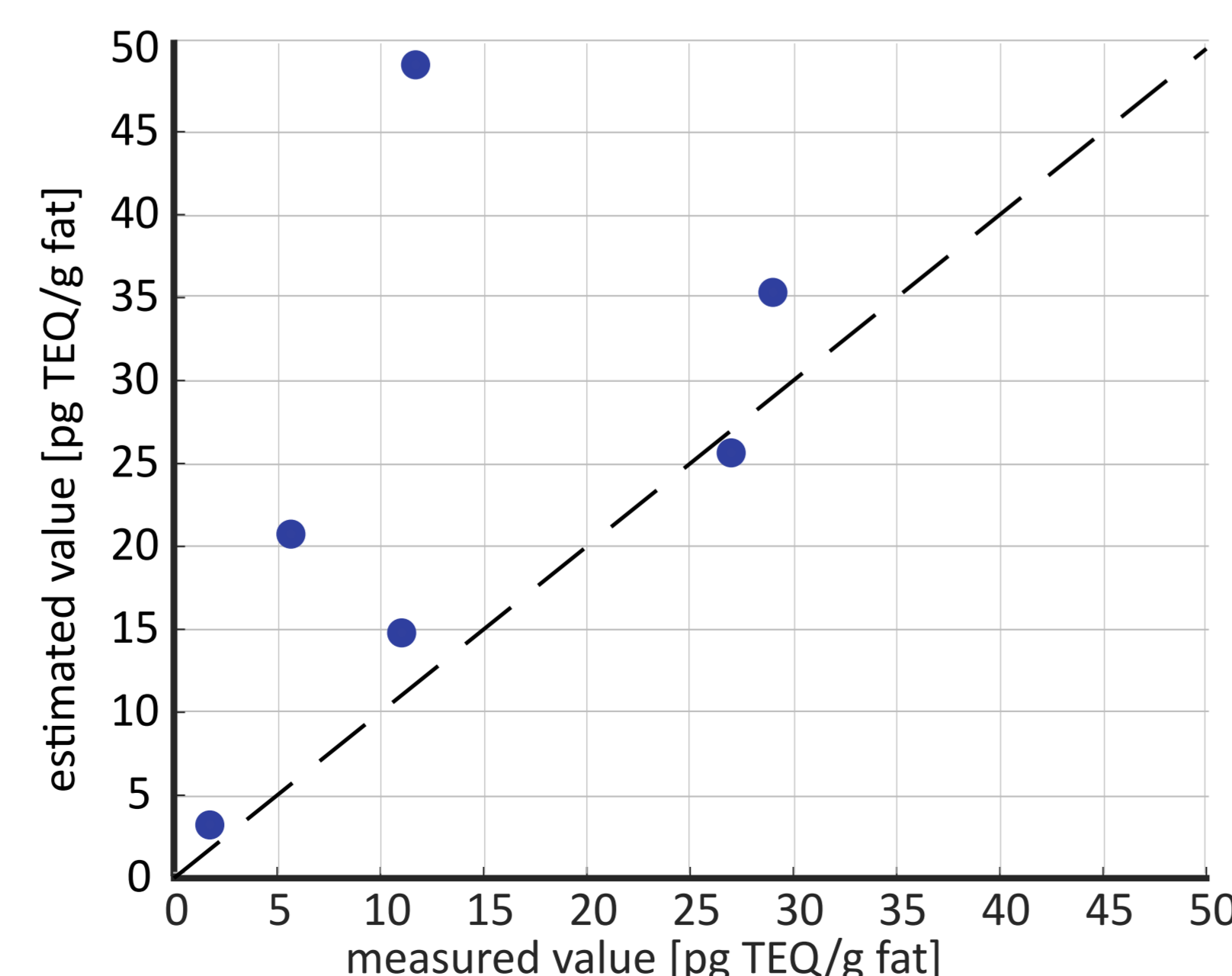


Figure 5: Relationship between the values measured in the eggs and the values predicted by the model

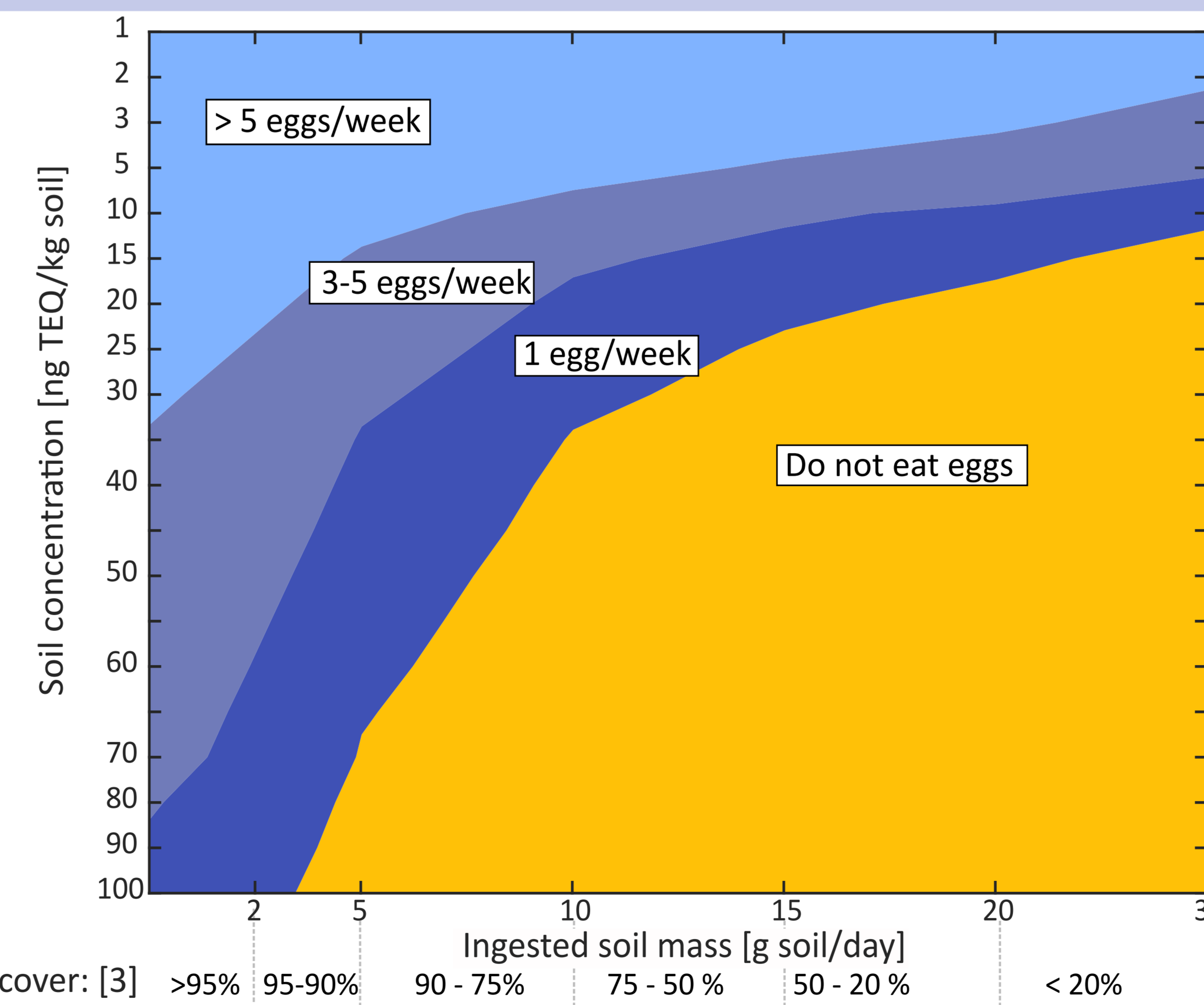
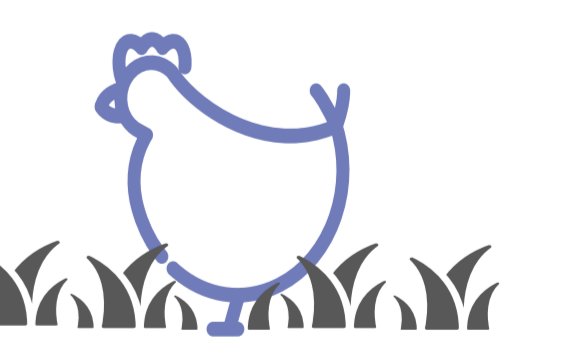


Figure 6: Recommendations for maximum consumption of eggs from hens raised on contaminated soils between 1 and 100 [ng TEQ/kg soil] depending on geophagy according to the Tolerable Daily Intake of 0.3 [pg TEQ/kg body weight/day] calculated for a 70 kg

Conclusion and Outcomes

- The main parameters that influence the eggs concentration are: **the soil concentration and the amount of ingested soil**

The geophagy should be reduced to the lowest with the soil coverage.



- The **frequency of consumption** is an important parameter to reduce the daily intake.



- To confirm this scenario of exposure is one of the most important, blood measurements of PCDD/Fs will be performed in the population. This next phase of the project will include a control group and a group "overexposed" people. The latter group will include people who keep a chicken coop and/or a vegetable garden on the contaminated soil.



[1]: Vernez et al., 2023, Polychlorinated dibenzo-p-dioxins (PCDDs) and dibenzofurans (PCDFs) soil contamination in Lausanne, Switzerland : Combining pollution mapping and human exposure assessment for targeted risk management

[2]: Van Eijkeren et al., 2006, A toxicokinetic model for the carry-over of dioxins and PCBs from feed and soil to eggs.

[3]: Waegeneers et al., 2009, Transfer of soil contaminants to home-produced eggs and preventive measures to reduce contamination