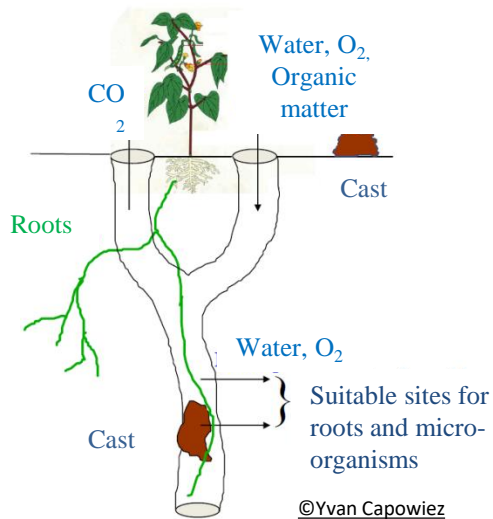
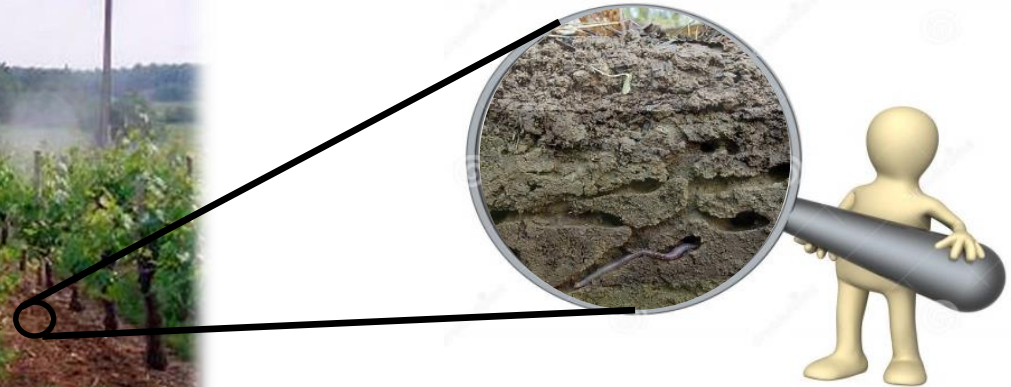


A biology-based model to analyze growth data of earthworms exposed to copper at different ages

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Copper treatment



Organic matter degradation



Soil structure



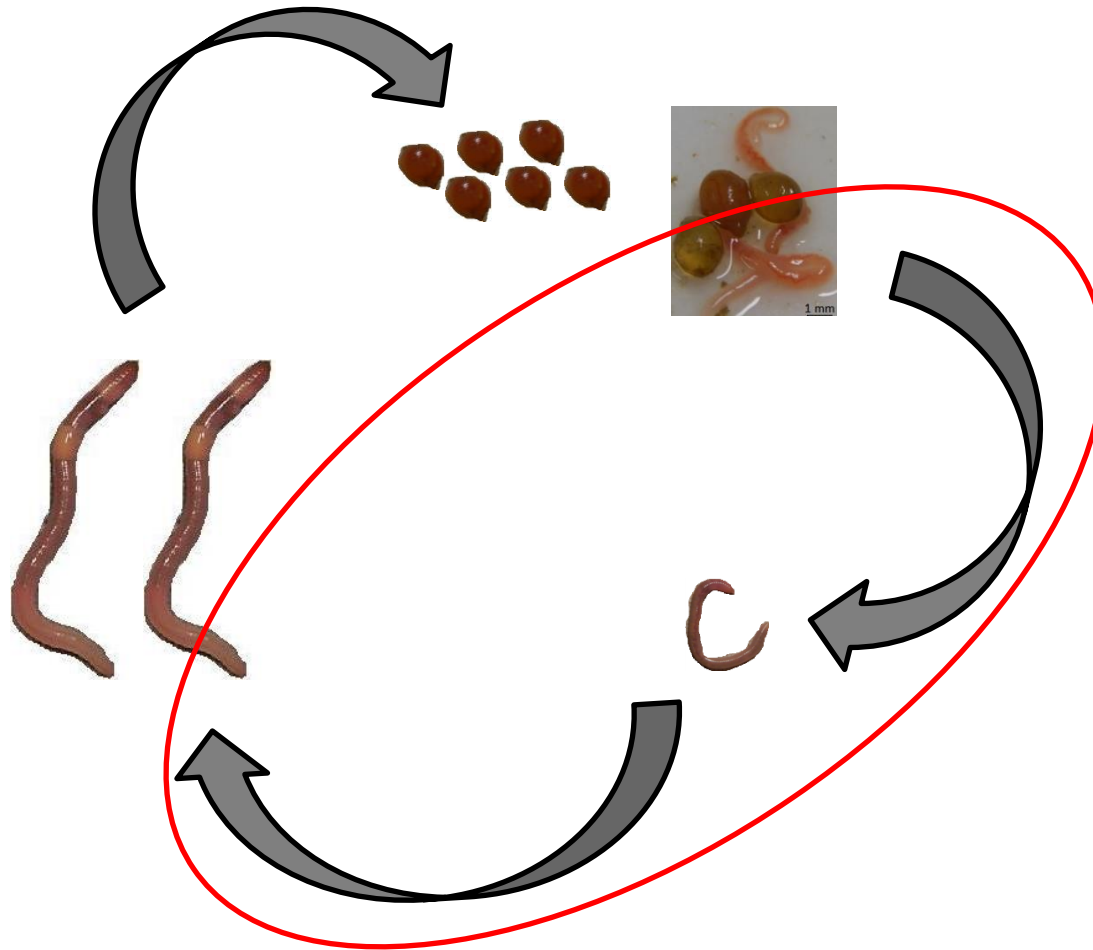
Water infiltration



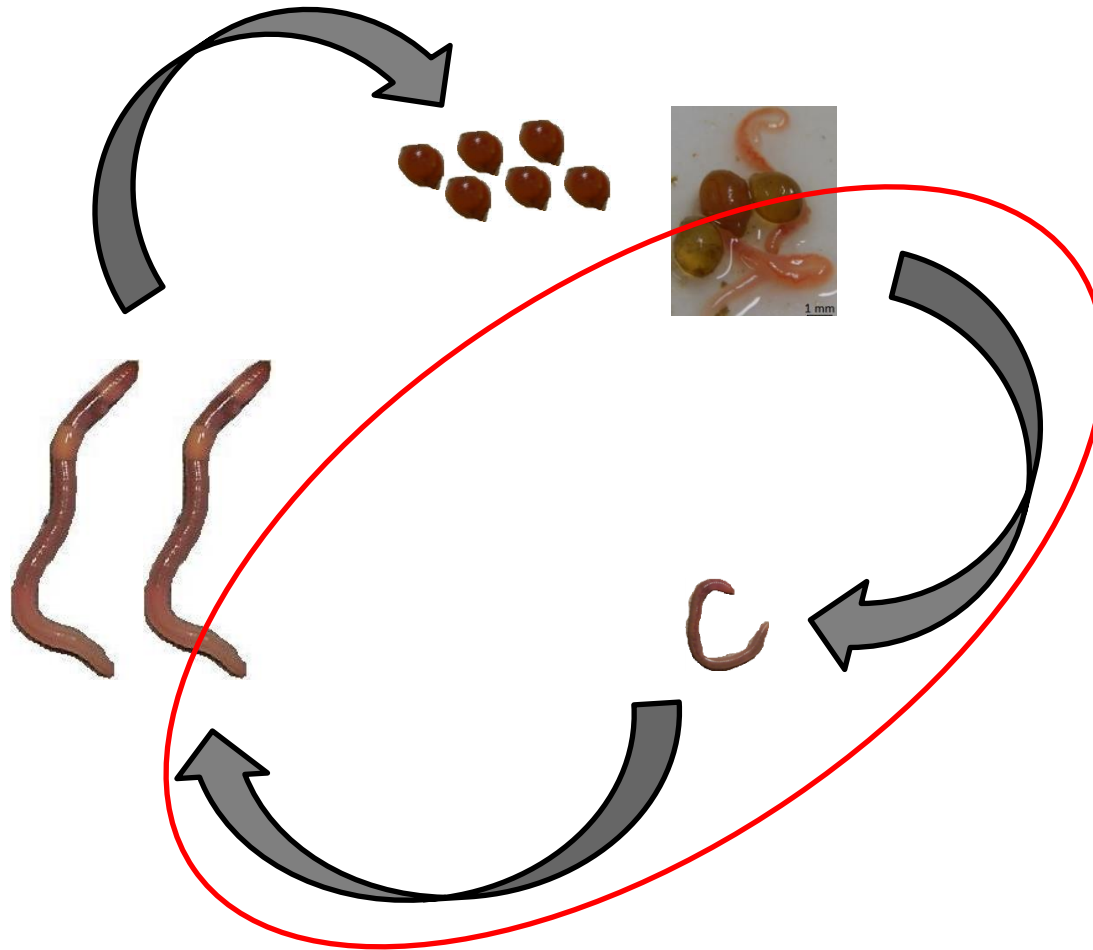
Gas exchange



Earthworms



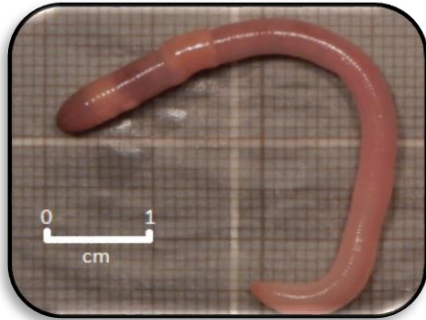
- The growth is an important parameter of the population dynamics
- There is no standardized test available for the assessment of chemicals on the growth period



→ Objective: Assess the impact of copper on earthworms growth and provide a relevant analysis of the results using a toxicokinetics (TK) model coupled with a biology-based toxicodynamic (TD) model.

Material and methods

A highly representative species of agroecosystems



Aporrectodea caliginosa s.s.
(Savigny, 1826)

An agricultural soil (meadow)



Loamy-clay soil



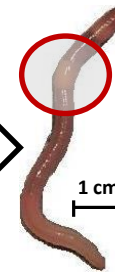
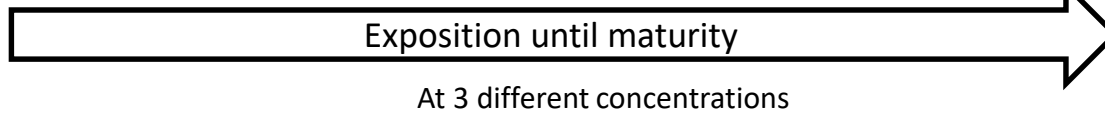
Cuprafor micro®:
Copper oxychloride (50%)

(INDUSTRIAS QUIMICAS DEL VALLES)

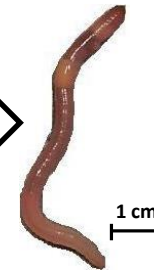
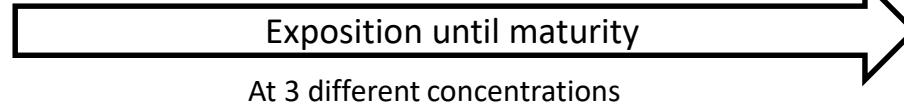
→ Sublethal concentrations applied
3.33 times the RD (25.8 mg kg^{-1})
10 times the RD (77.5 mg kg^{-1})
30 times the RD (232.5 mg kg^{-1})



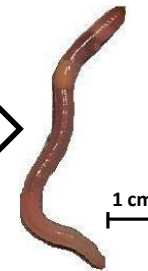
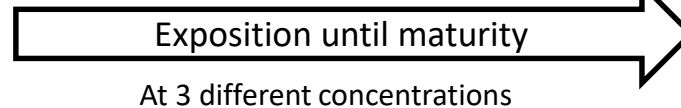
Age 1
(0 day)



Age 2
(28 days)



Age 3
(56 days)



- ❖ One individual per vessel
- ❖ Fed *ad libitum*
- ❖ Climate room (15 °C)

The biology-based model

Assumptions:

- Isomorphic growth
- Low maintenance costs

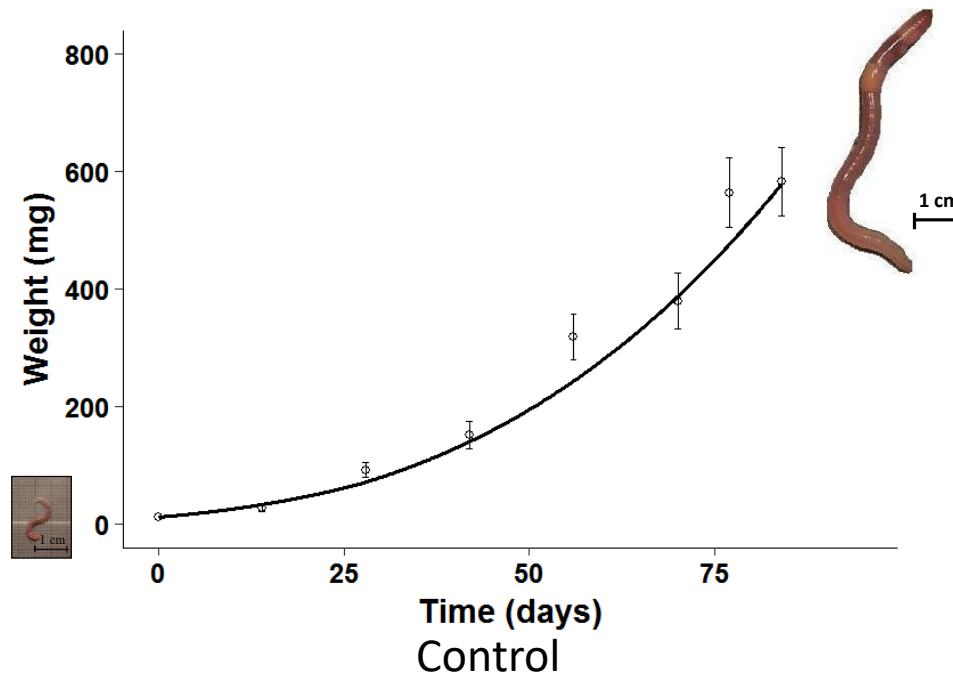
→ In the case of *ad libitum* food, this leads to the equation:

$$\frac{dl}{dt} = a$$

« l » is the wet weight cubic root

« a » is a constant

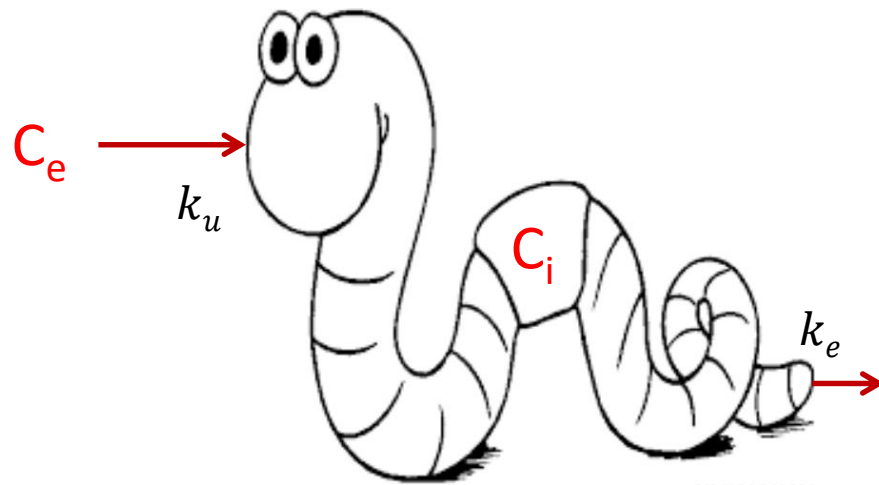
$$\text{Weight(mg)} = (at + l_0)^3$$



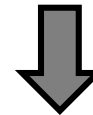
Control

The toxicokinetic-toxicodynamic model

The one compartment model

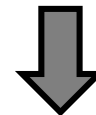


$$\frac{dC_i(t)}{dt} = k_u C_e(t) - k_e C_i(t)$$



The internal concentration is scaled by the bio-concentration factor

$$\frac{dc_i(t)}{dt} = k_e (C_e(t) - c_i(t))$$

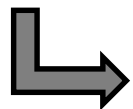


$c_i(t)$ is proportional to the concentration in the tissue, but has the dimension of an external concentration.

Dilution by growth (Kooijman & Bedaux, 1996)

$$\frac{dc_i(t)}{dt} = \frac{k_e (C_e(t) - c_i(t))}{l} - \frac{3a c_i}{l}$$

If $c_i > \text{NEC}$ (No Effect Concentration)



hypothesis: increase of the growth energy costs



proportional effects " b " to the difference between the c_i and the NEC

$$\frac{dl}{dt} = a$$



$$\frac{dl}{dt} = \frac{a}{1 + b \times (c_i(t) - \text{NEC})}$$

Results and Discussion

Because of a drastic inhibition of growth, we simplified the toxicodynamic model because « b » is expected to be very big

If $c_i > \text{NEC}$

~~$$\frac{dl}{dt} = \frac{a}{1 + b \times (c_i(t) - \text{NEC})}$$~~

$$\frac{dl}{dt} = 0$$

Only 2 parameters:

- the kinetics k_e
- the NEC



$$\frac{dc_i(t)}{dt} = \frac{k_e (C_e(t) - c_i(t))}{l} - \frac{3a c_i}{l}$$

- We estimate simultaneously the 2 parameter values on the all data (including the 3 different ages)

Age of exposure:



Age of exposure:

k_e	1.1839 (1.1731 - 1.7513)
NEC (mg Cu kg ⁻¹)	65.006 (64.795 - 65.010)



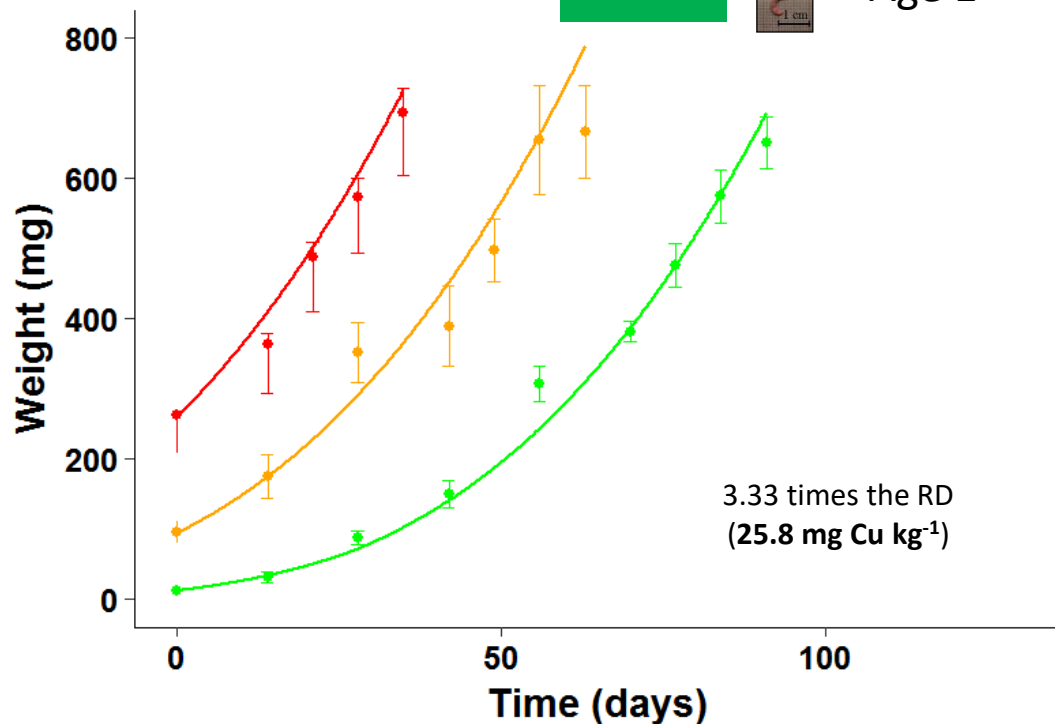
Age 3



Age 2

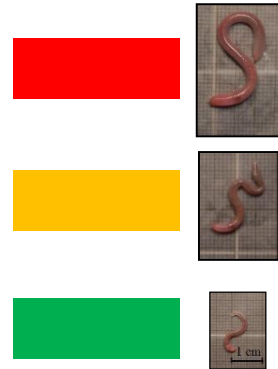


Age 1



→ No effect at 3.33 times the RD (25.8 mg Cu kg⁻¹)

Age of exposure:

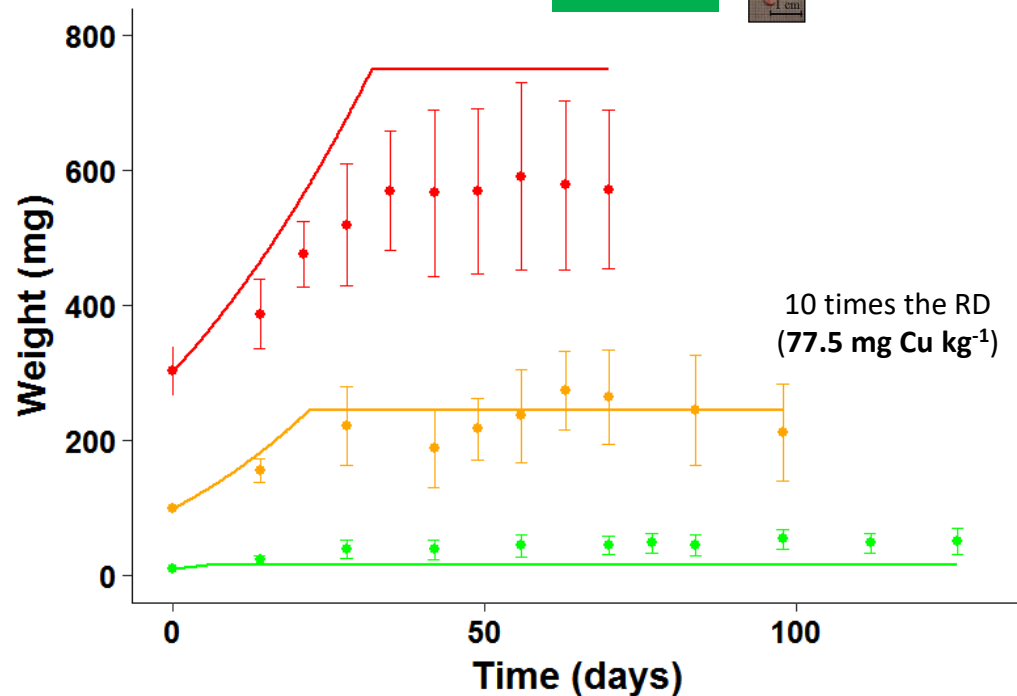
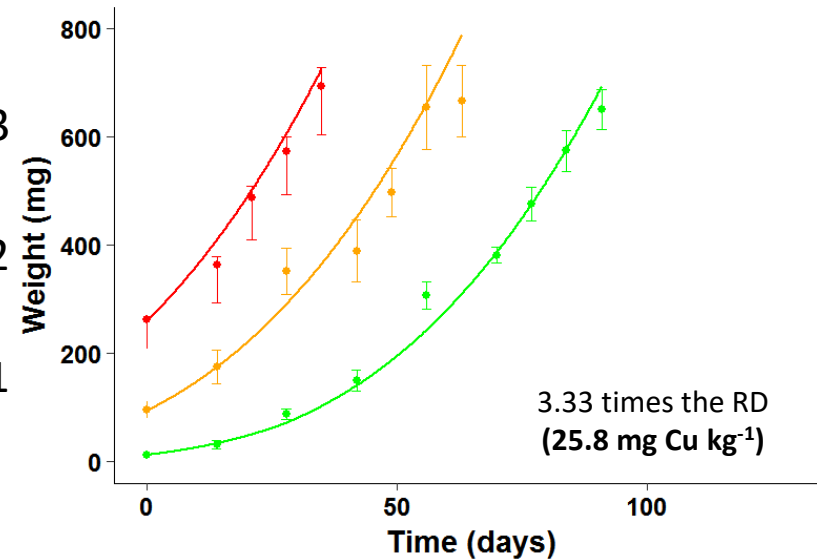


Age 3

Age 2

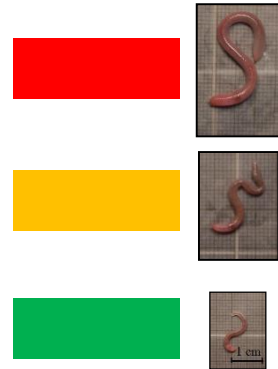
Age 1

k_e	1.1839 (1.1731 - 1.7513)
NEC (mg Cu kg ⁻¹)	65.006 (64.795 - 65.010)



→ A growth inhibition depending on the age of exposure (importance of the dilution by growth in the toxicokinetic model)

Age of exposure:

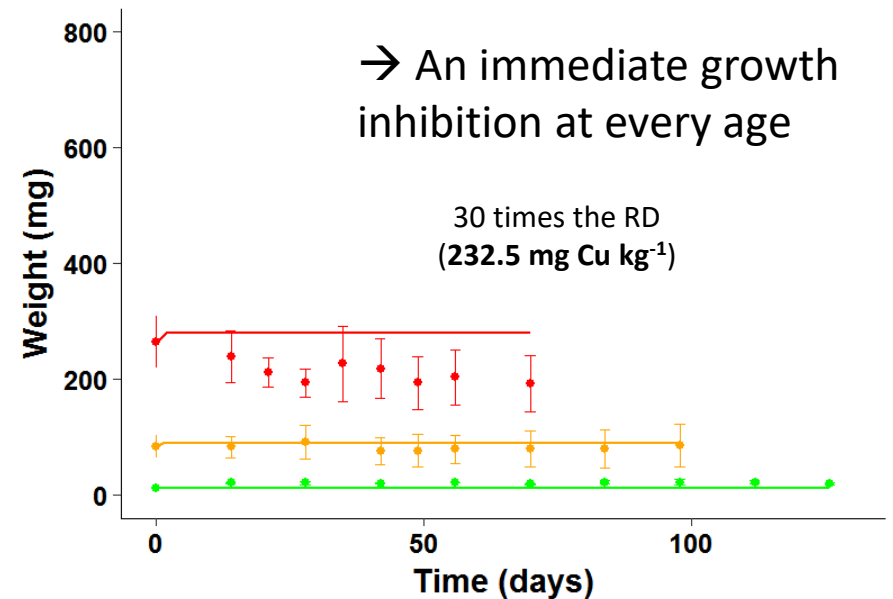
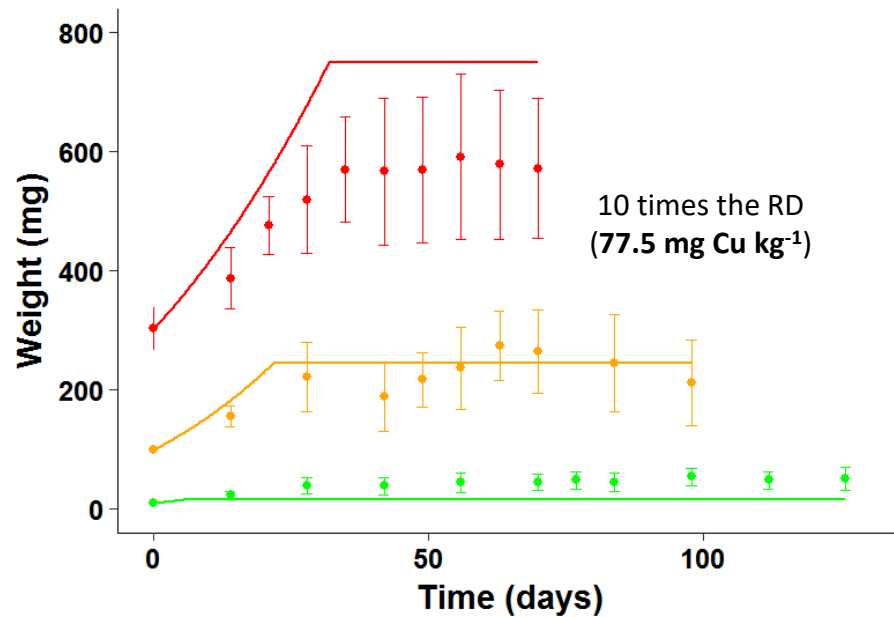
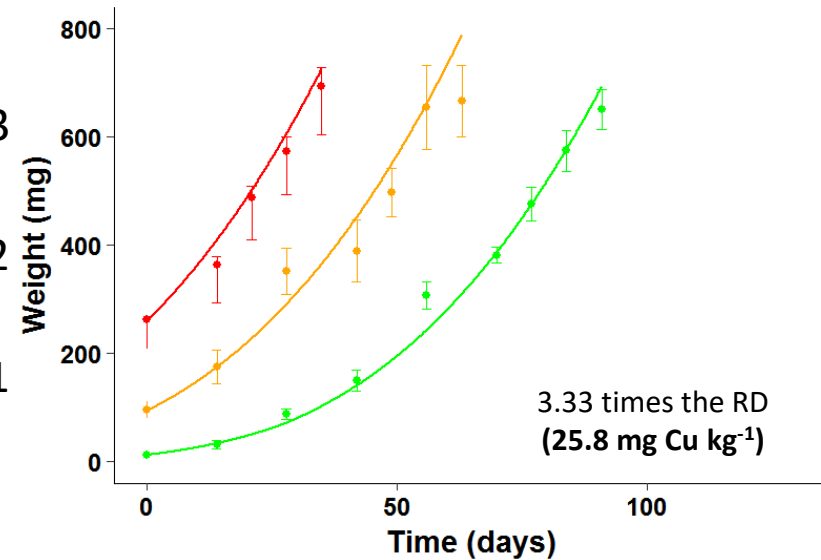


Age 3

Age 2

Age 1

k_e	1.1839 (1.1731 - 1.7513)
NEC (mg Cu kg ⁻¹)	65.006 (64.795 - 65.010)



Conclusion

- The biology-based model provided a relevant analysis of the toxicity data and the copper toxicity depends on the kinetics which is faster for small individuals.
- The model provided a NEC (No Effect Concentration) value (65 mg kg^{-1}), which does not depend on the time of exposure, and which is common to the 3 different ages.
- Copper appeared highly harmful for earthworm growth over the NEC which correspond to 8.4 times the RD.

Thanks you for your attention



→ L o o k i n g f o r a
p o s t- d o c t o r a l
p o s i t i o n

**Good bye
earthworms...and
what will be the
next adventure !?!**

I will
miss you



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Keywords of my research:

- ❖ Ecotoxicology
- ❖ Modelling
- ❖ Invertebrate
- ❖ Risk assessment
- ❖ Field and laboratory study
- ❖ Pesticides and metals

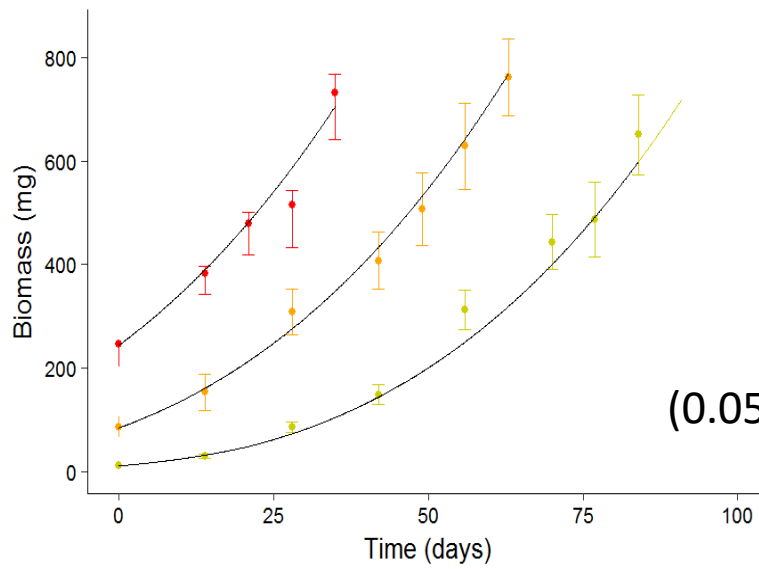
$$\frac{dC_i(t)}{dt} = k_u C_e - k_e C_i$$

$$BCF = \frac{k_u}{k_e} \quad C_i = \frac{C_i(t)}{BCF} \quad \longrightarrow \quad C_i = c_i \frac{k_u}{k_e}$$

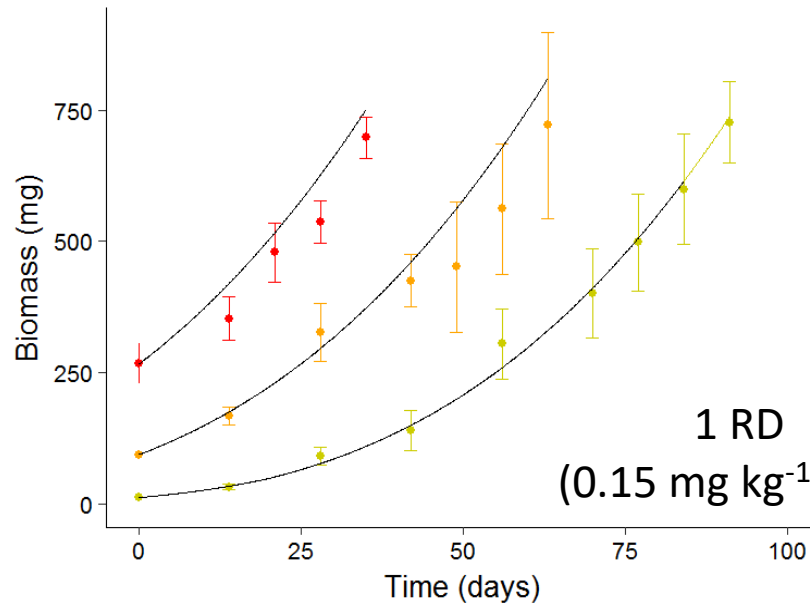
$$\frac{dc_i(t)}{dt} \frac{k_u}{k_e} = k_u C_e - \cancel{k_e} c_i \cancel{\frac{k_u}{k_e}}$$

$$\frac{dc_i(t)}{dt} \cancel{\frac{k_u}{k_e}} = \cancel{k_u} C_e - \cancel{k_u} c_i$$

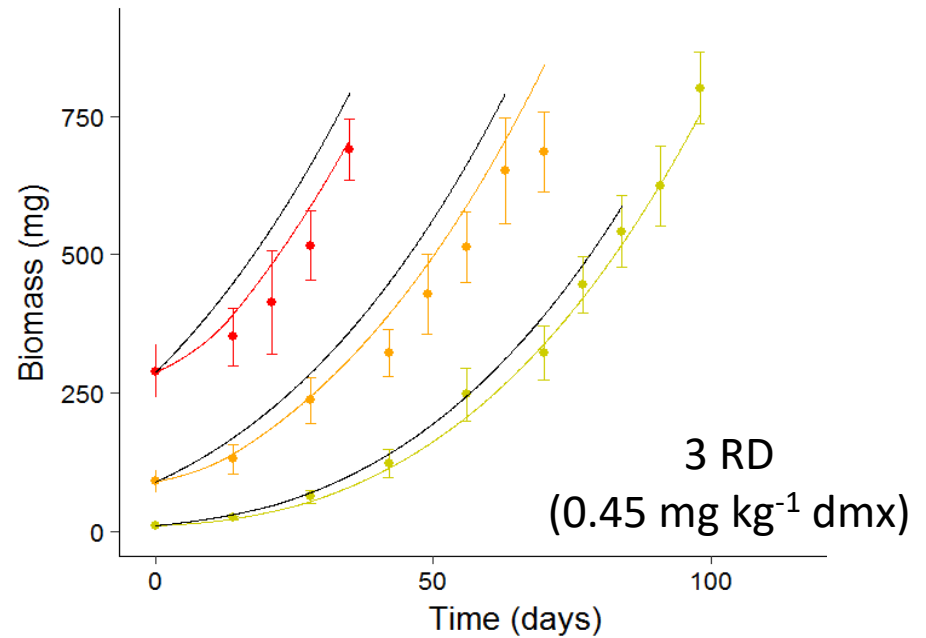
$$\frac{dc_i(t)}{dt} = k_e (C_e - c_i)$$



0.33 RD
(0.05 mg kg⁻¹ dmx)



1 RD
(0.15 mg kg⁻¹ dmx)



3 RD
(0.45 mg kg⁻¹ dmx)

Table 1.Characteristic of the LPC soil (n = 7, \pm SE)

Characteristic	LPC soil
Clays ($< 2 \mu\text{m}$, g kg^{-1})	226 ± 6.25
Fine silt (2-20 μm , g kg^{-1})	174.14 ± 3.03
Coarse silt (20-50 μm , g kg^{-1})	298.86 ± 12.76
Fine sand (50-200 μm , g kg^{-1})	239.14 ± 8.85
Coarse sand (200-2000 μm , g kg^{-1})	47.86 ± 3.84
CaCO ₃ total (g kg^{-1})	23.25 ± 8.06
Organic matter (g kg^{-1})	32.64 ± 1.69
P ₂ O ₅ (g kg^{-1})	0.08 ± 0.006
Organic carbon (g kg^{-1})	18.86 ± 0.98
Total nitrogen (N) (g kg^{-1})	1.49 ± 0.07
C/N	12.69 ± 0.32
pH	7.5 ± 0.21
Cu ^{tot} (mg kg^{-1})	25.23 ± 1.6