Fluxes of the ^{238}U series within the Dicalcium Phosphate industrial production and the biokinetical analysis of ^{210}Pb and ^{210}Po in broilers due to its ingestion

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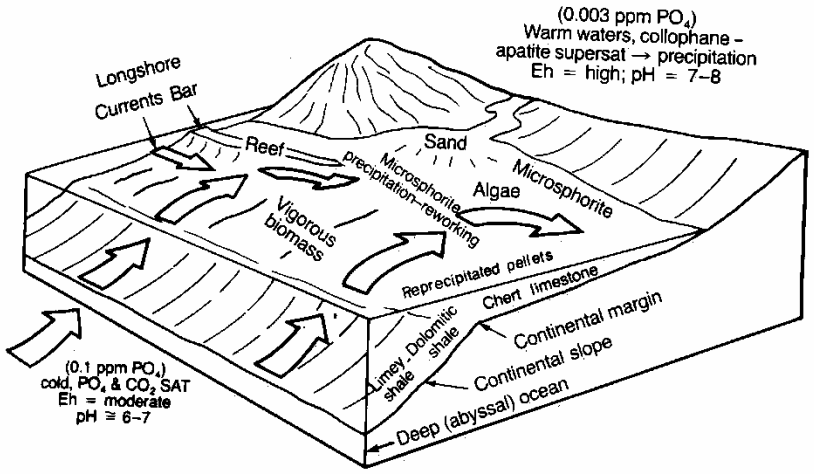
Outline

- **Introduction**
  - **Dicalcium phosphate (DCP)**
  - **Radionuclide incorporation to chickens due to ingestion of DCP**
  - **Aims of the work**
- **Materials & methods**
- **Results (and discussion)**
  - **Fluxes of radionuclides in the DCP production process**
  - **Accumulation of ^{210}Pb and ^{210}Po in chickens and a biokinetical approach.**
- **Conclusions**

Dicalcium Phosphate

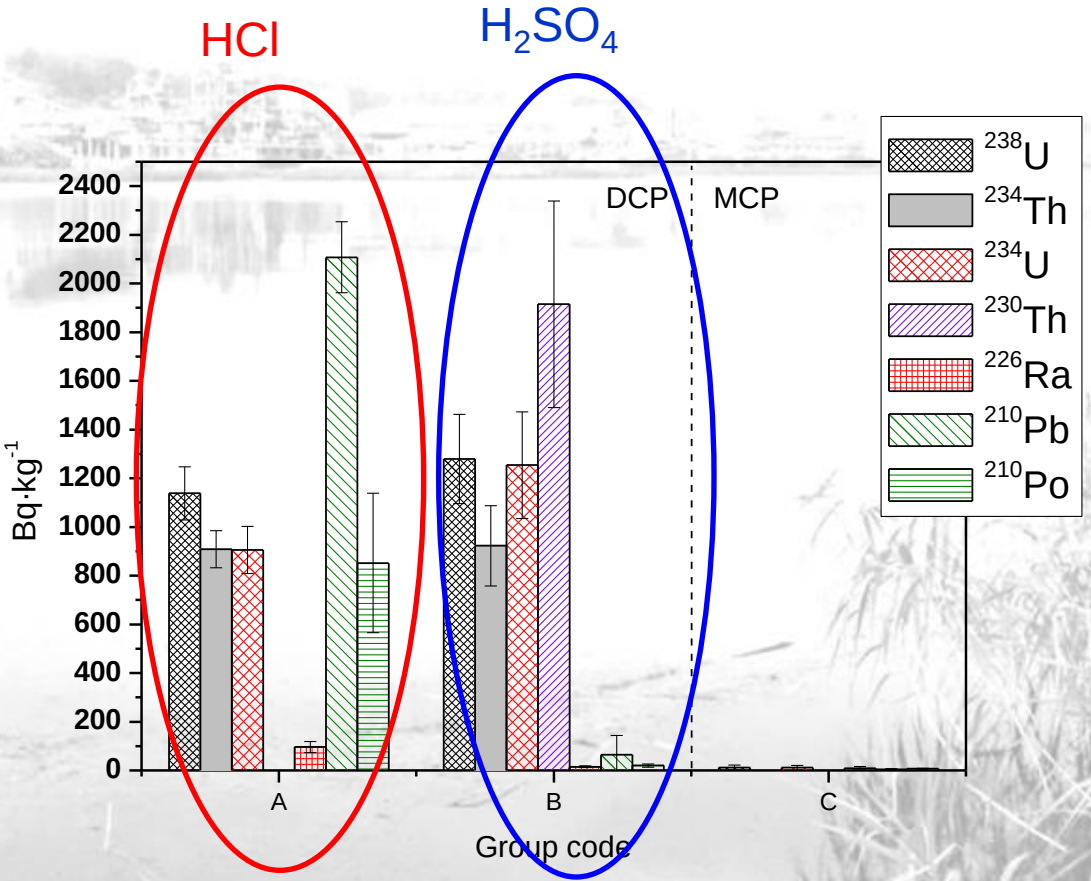
- **Dicalcium Phosphate is a calcium feed supplement for domestic animals (cattle, poultry, etc.).**
- **High calcium availability (93%).**
- **Produced through the rock acid digestion with either HCl or H_2SO_4 (Gäfvert et al., 2001).**
- **Replacement of calcium by uranium in the apatite structure**

$^{238}U > 10^3$ Bq·kg^{-1}
(Burnett and Veeh., 1992)



Dicalcium Phosphate

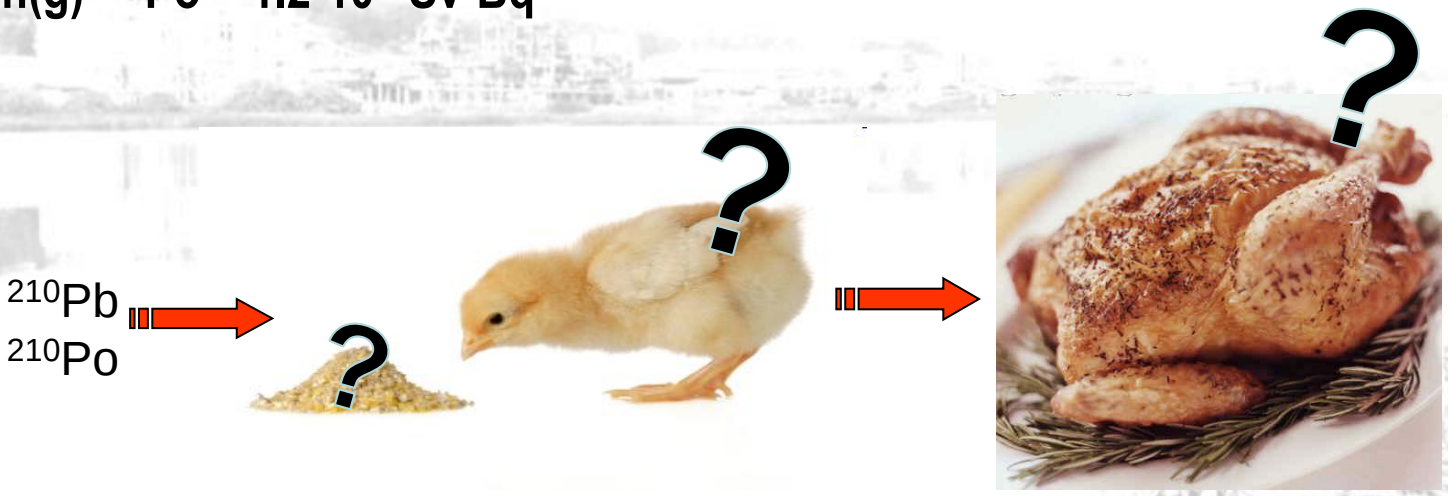
- **Previous studies shown that depending on the acid used, different radionuclides are accumulated in the final product (Casacuberta et al., 2009).**



Specific concentrations ^{210}Pb ~ **2000 Bq·kg^{-1}** and ^{210}Po **~800 Bq·kg^{-1}**

Radionuclide incorporation in animals

- **^{210}Pb and ^{210}Po are of special interest since its accumulation in food might pose a potential radiological dose by ingestion. h(g) ^{210}Pb = 6.9·10^{-7} Sv·Bq^{-1}; h(g) ^{210}Po = 1.2·10^{-6} Sv·Bq^{-1}**



- **Accumulation of radionuclides in animals and humans depends on:**
  - **the rate of intake,**
  - **gastrointestinal absorption, and**
  - **turnover in tissues.**

Aims of the work

- Elucidate the fluxes of the isotopes of the ^{238}U decay series in the production process of DCP;
- Examine the accumulation of ^{210}Pb and ^{210}Po in chicken tissues during its growth as a function of the type and amount of DCP in chicken diets as well as its contents of radionuclides; and
- Build a suitable kinetic model to understand the distribution of ^{210}Pb and ^{210}Po within chicken tissues after ingestion.

MATERIALS & METHODS

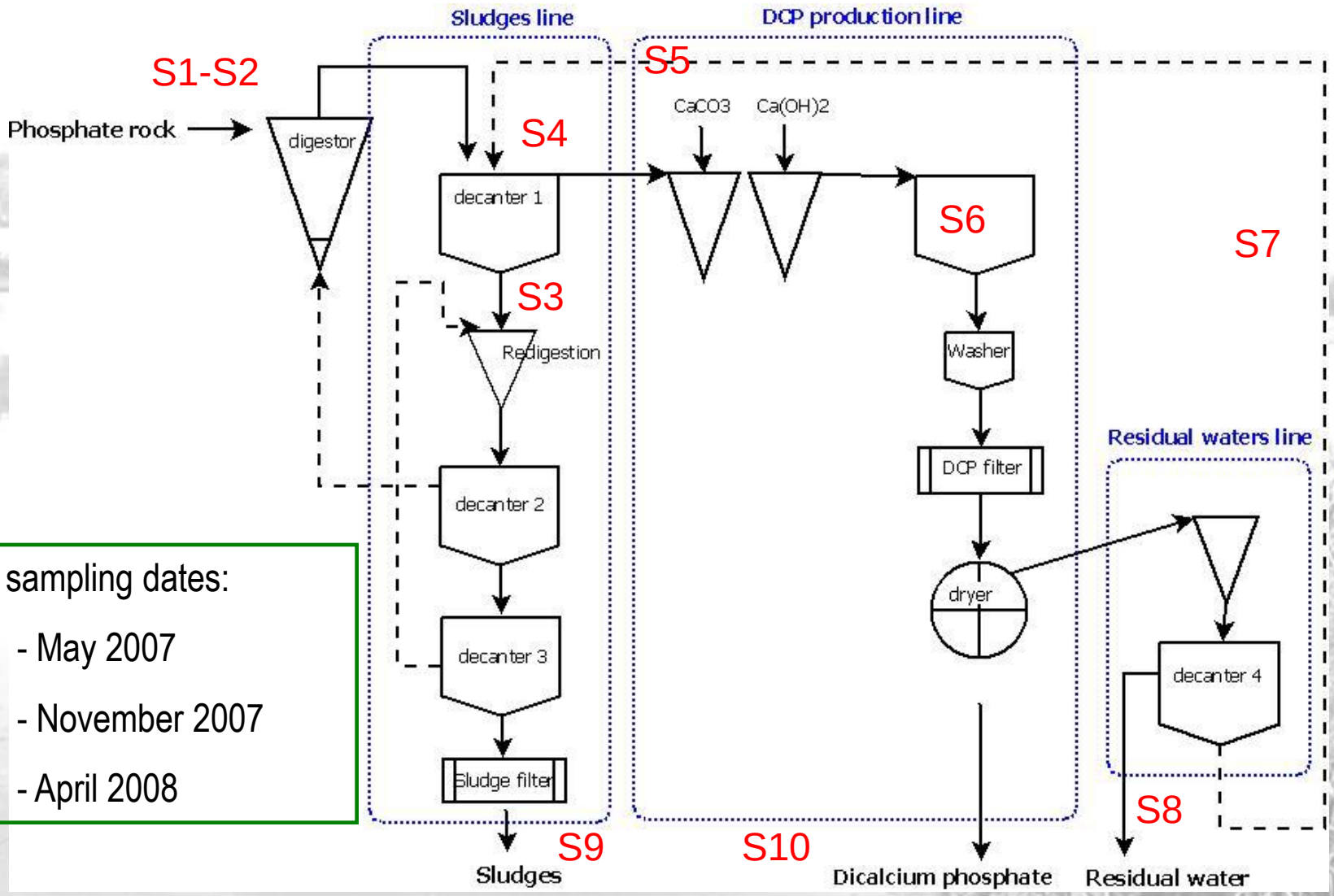
Materials and Methods

- **Fluxes of radionuclides within the DCP production process;**
  - **Sampling**
  - **Radionuclide analysis**

- **Accumulation of ^{210}Pb and ^{210}Po in chickens;**
  - **Experimental set-up**
  - **Biokinetic model for ^{210}Pb and ^{210}Po in chickens.**

MATERIALS & METHODS

Industrial samples



x 3 sampling dates:

- May 2007
- November 2007
- April 2008

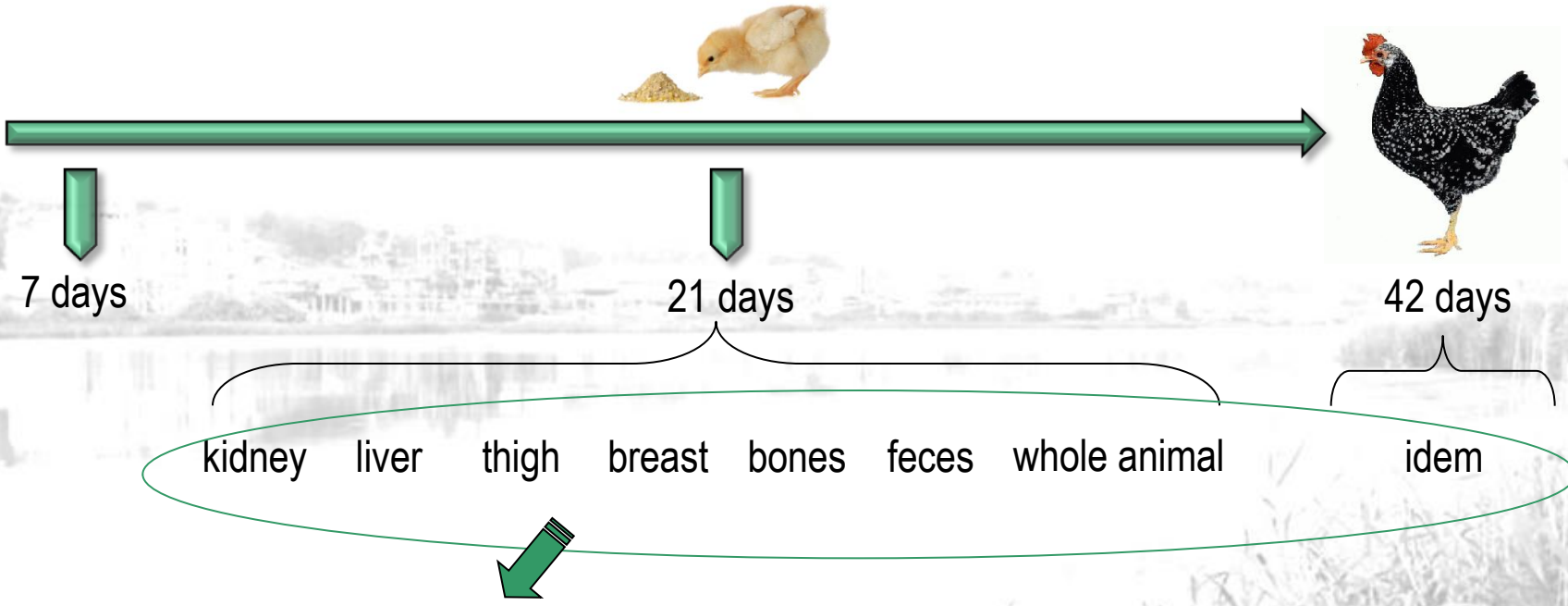
MATERIALS & METHODS

Radionuclides analysis

- ^{238}U, ^{234}U, ^{230}Th : radiochemical purification (Horwitz et al., 1992), electrodeposition and alpha spectrometry (EG&Ortec Mod. SSB 450 R).
- ^{226}Ra: gamma spectrometry (GMX,EG&G Ortec): ^{214}Pb (295, 351 keV) and ^{214}Bi (609 keV).
- ^{210}Pb, ^{210}Po: acid digestion, deposition of ^{210}Po in silver disks and alpha spectrometry. Ingrowth decay corrections of ^{210}Pb and ^{210}Po at sampling date (Masqué et al., 2002).

MATERIALS & METHODS

Accumulation of ^{210}Pb and ^{210}Po in chickens



Diet A: blank diet (~2 Bq·kg^{-1} ^{210}Pb and ^{210}Po)

Diet B: 2.5% DCP* (~60 Bq·kg^{-1} ^{210}Pb and ^{210}Po)

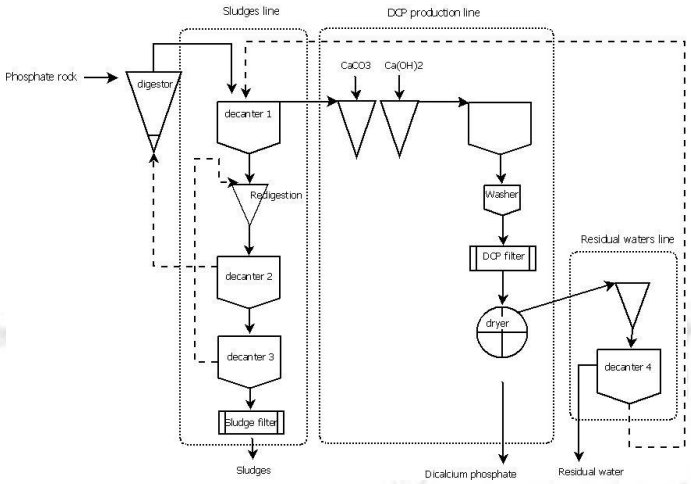
Diet C: 5% DCP* (~100 Bq·kg^{-1} ^{210}Pb and ^{210}Po)

* DCP: 1700 Bq·kg^{-1} ^{210}Pb and ^{210}Po

RESULTS

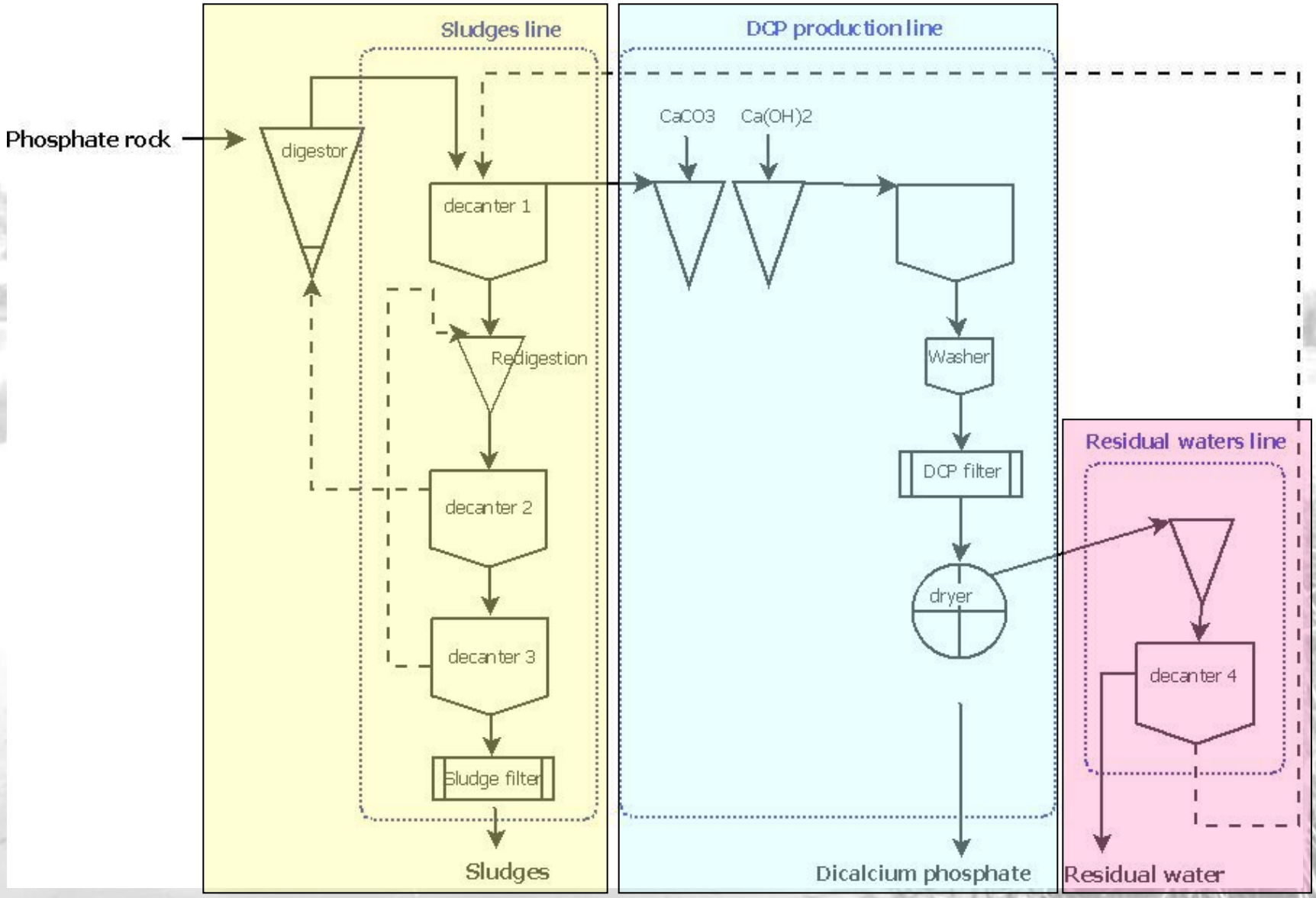
Results and discussion

- **Fluxes of radionuclides within the DCP production process.**
- **Accumulation of ^{210}Pb and ^{210}Po in chickens.**
- **Biokinetic model for ^{210}Pb and ^{210}Po in chickens.**



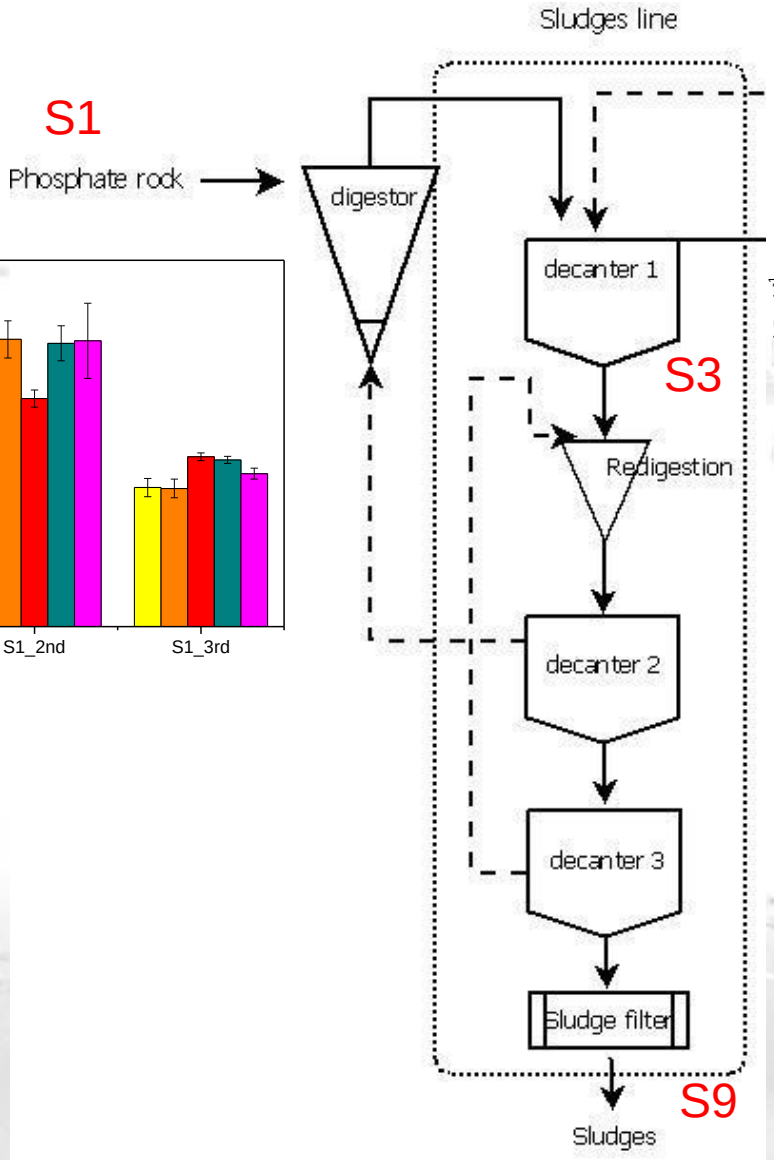
RESULTS

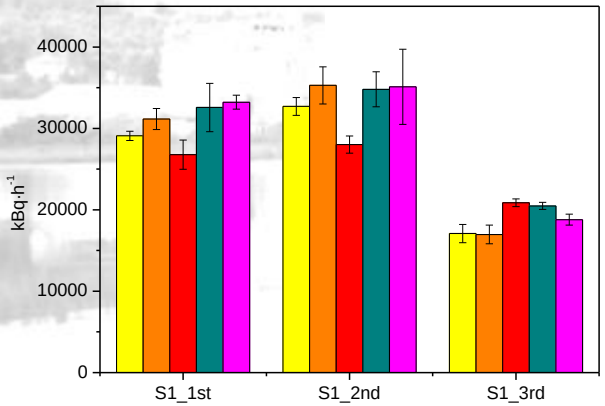
Fluxes of radionuclides within the DCP production process

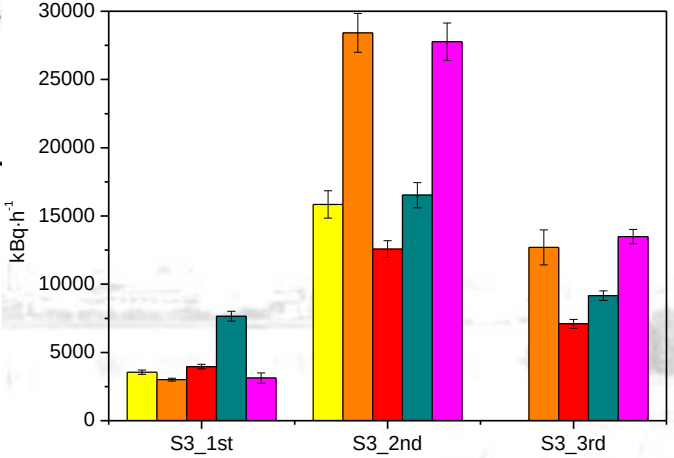


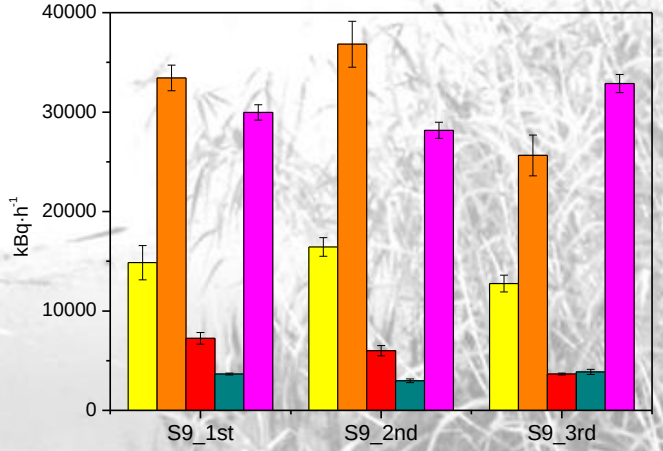
RESULTS

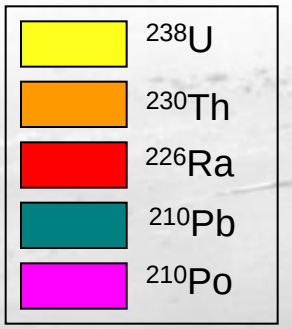
Fluxes in the sludges line (kBq·h^{-1})





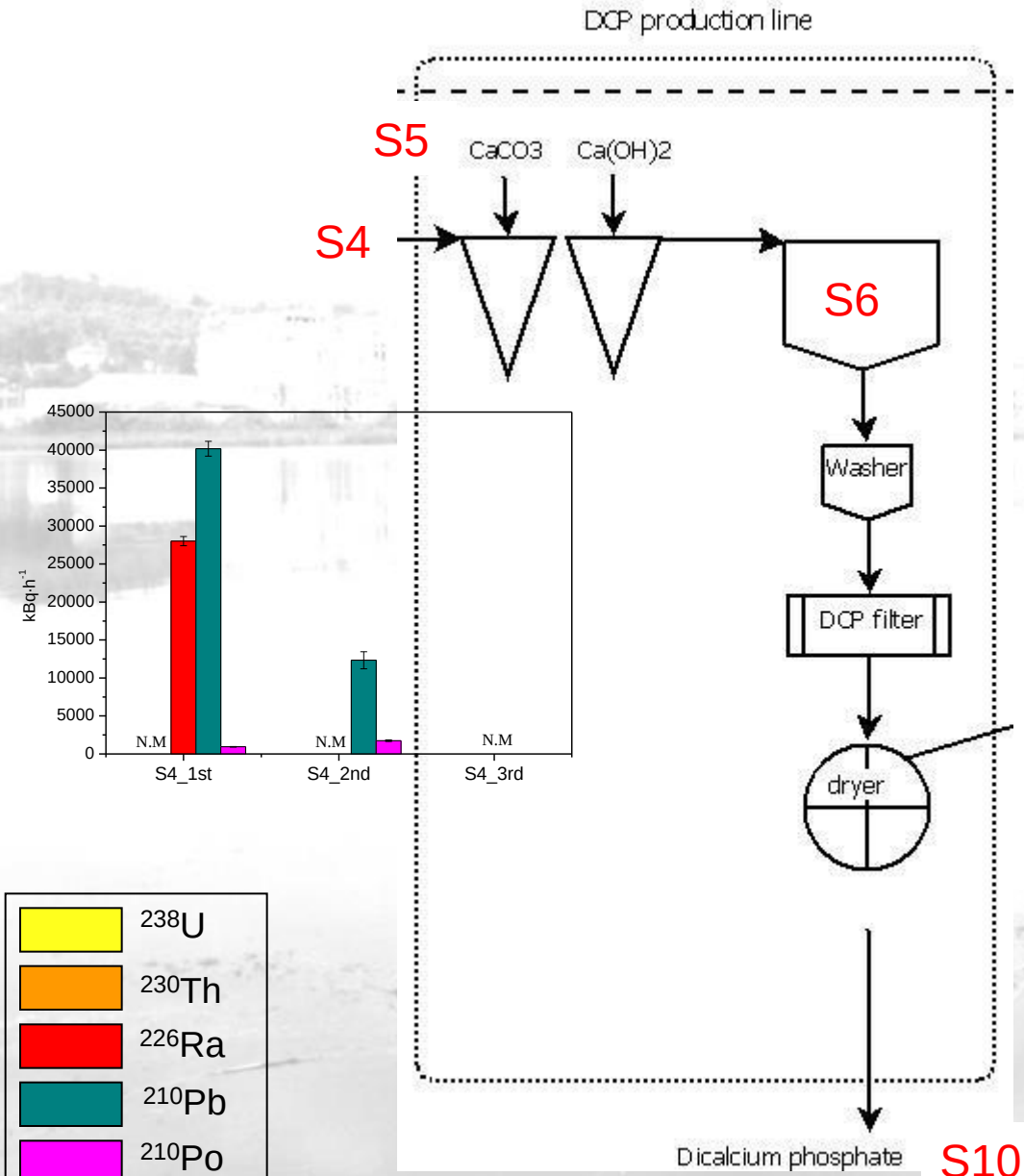


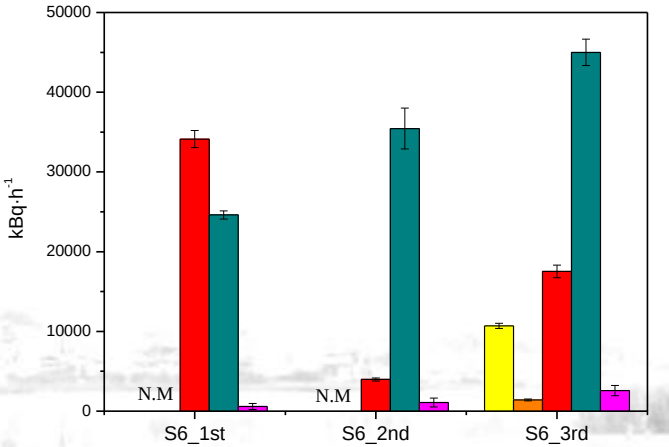


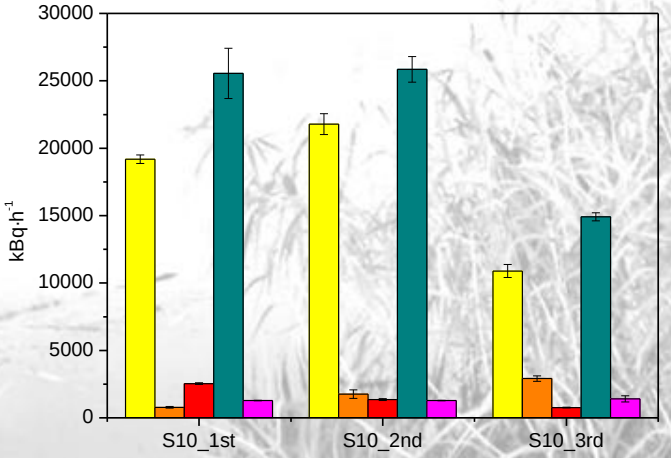


RESULTS

Fluxes in DCP production line (kBq·h^{-1})

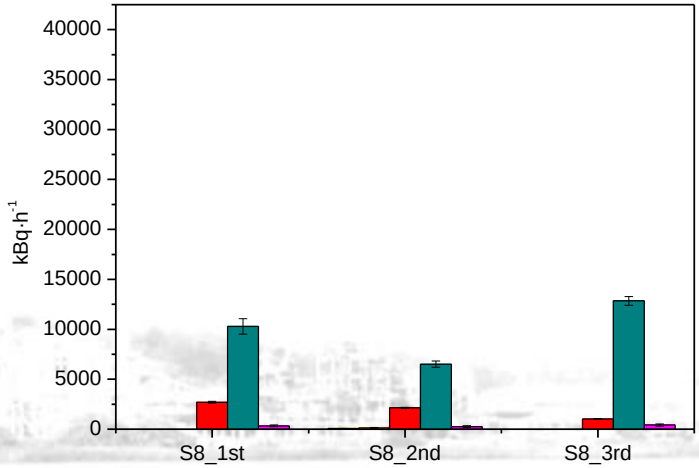


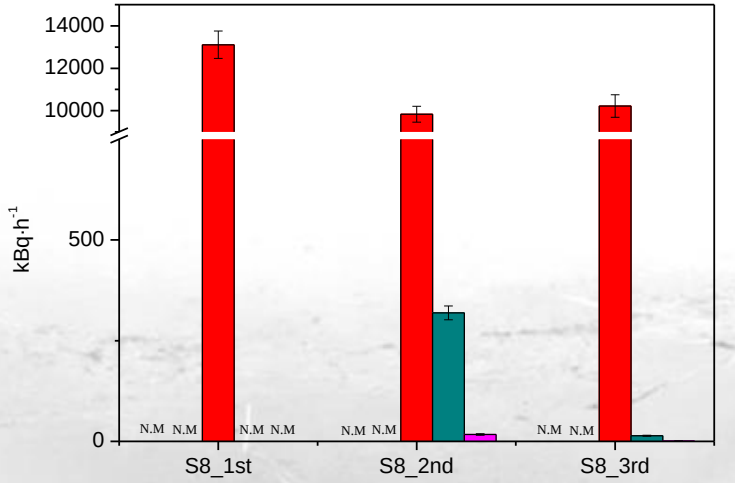


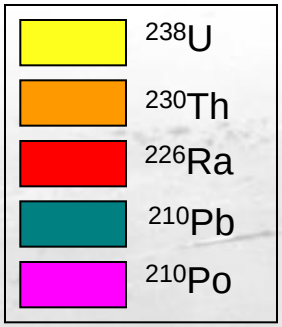


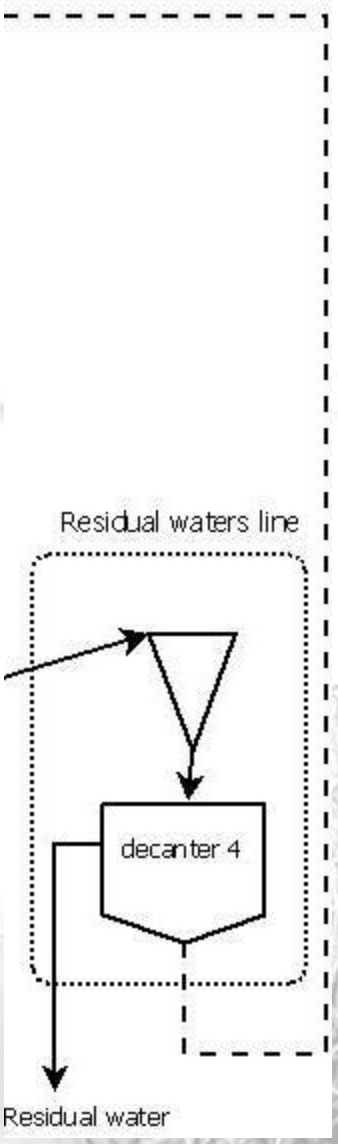
RESULTS

Fluxes waters and recirculation line (kBq·h^{-1})



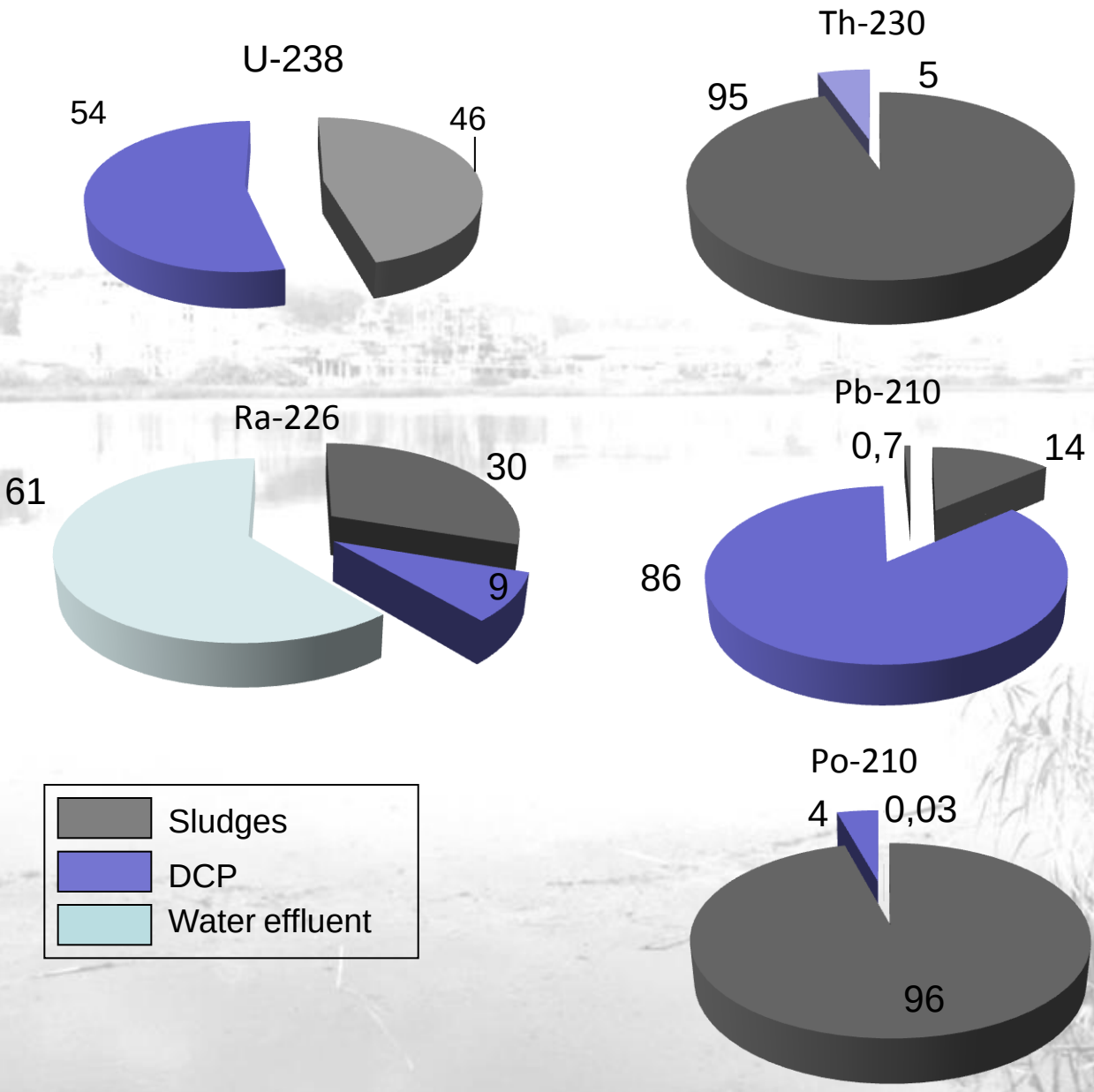






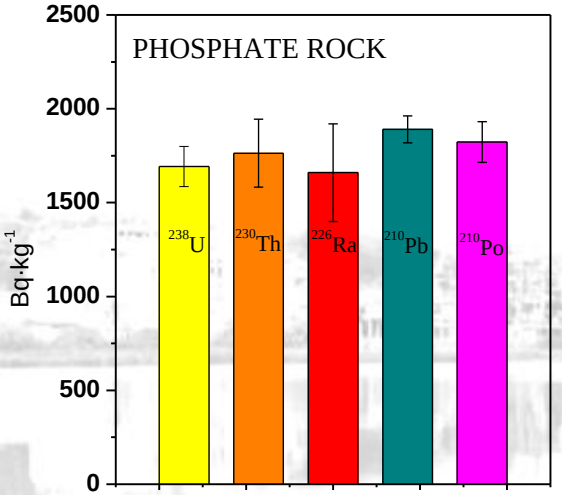
RESULTS

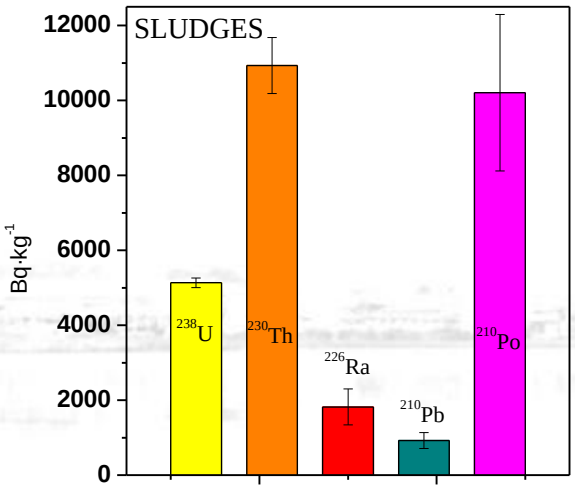
Radionuclide outputs

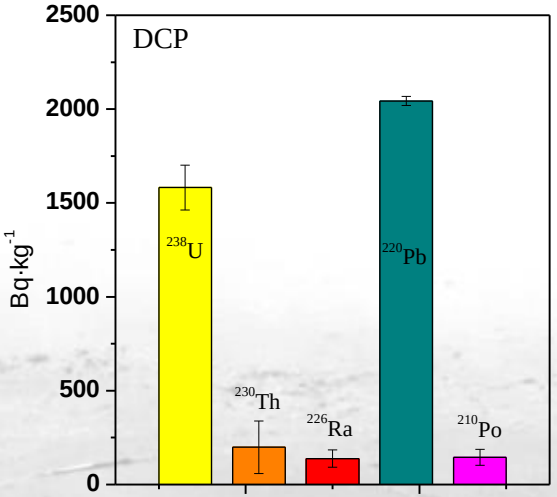


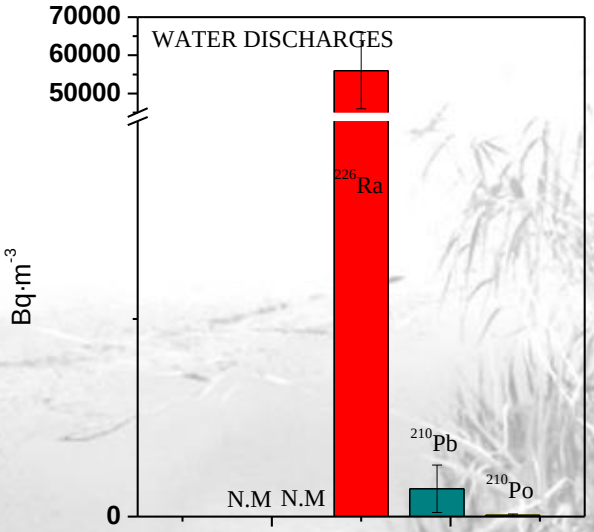
RESULTS

Specific concentrations of radionuclides









Exemption and clearance criteria

New European Basic Safety Standards:

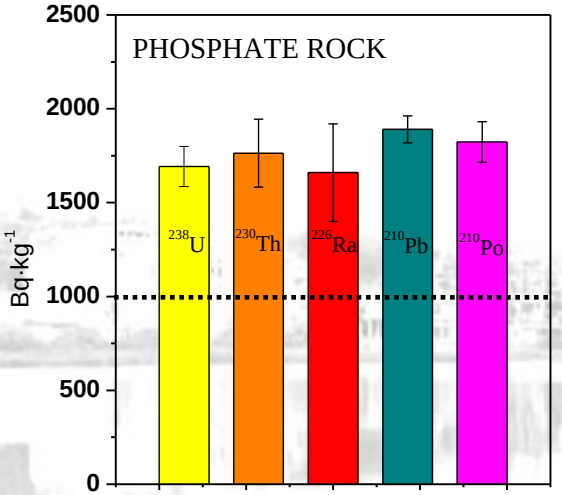
The exempt activity concentration values ($Bq \cdot g^{-1}$) for the materials involved in the practice for Naturally Occurring Radionuclides is:

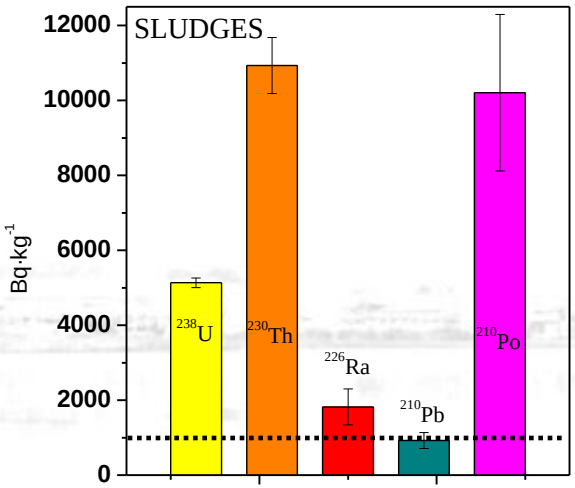
- **Natural radionuclides from the U-238 series 1 $kBq \cdot kg^{-1}$**
- **Natural radionuclides from the Th-232 series 1 $kBq \cdot kg^{-1}$**
- **K-40 10 $kBq \cdot kg^{-1}$**

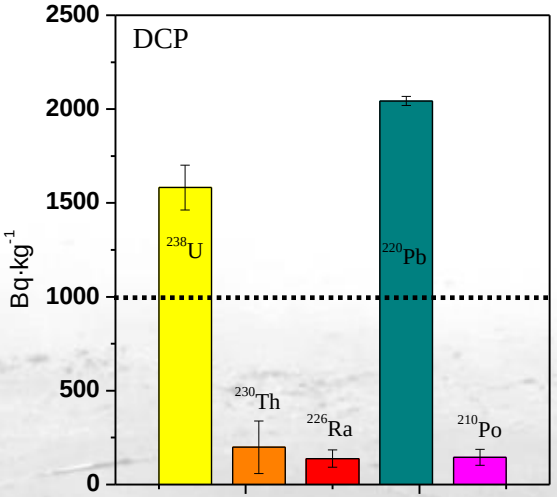
Some elements in the decay chain, e.g. ^{210}Pb and ^{210}Po may warrant the use of values by up to two orders of magnitude.

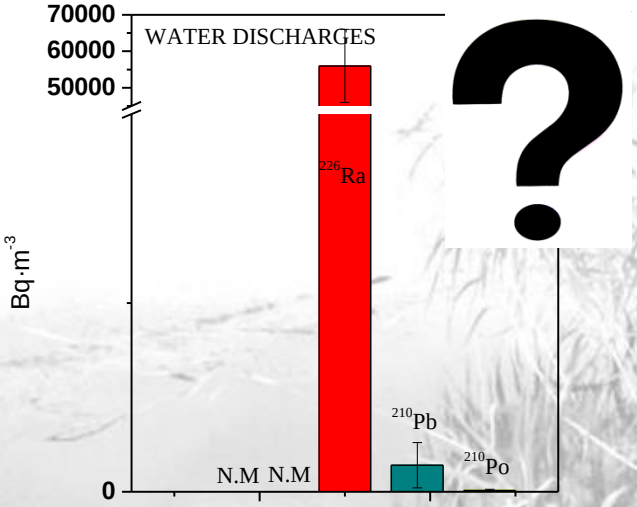
RESULTS

Exemption and clearance criteria



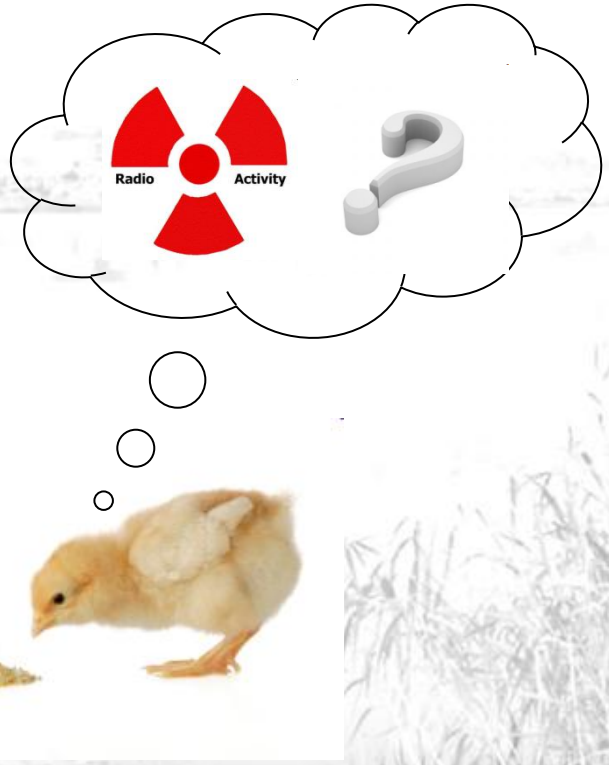






RESULTS

Accumulation of ^{210}Pb and ^{210}Po in chickens due to the ingestion of DCP



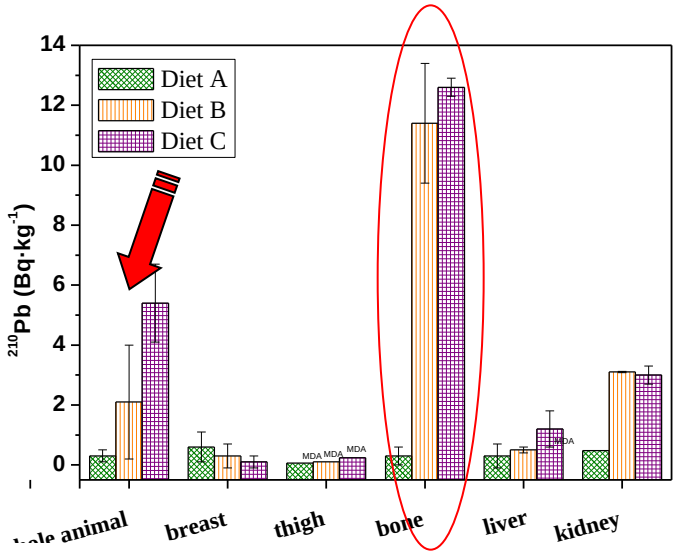
^{210}Pb

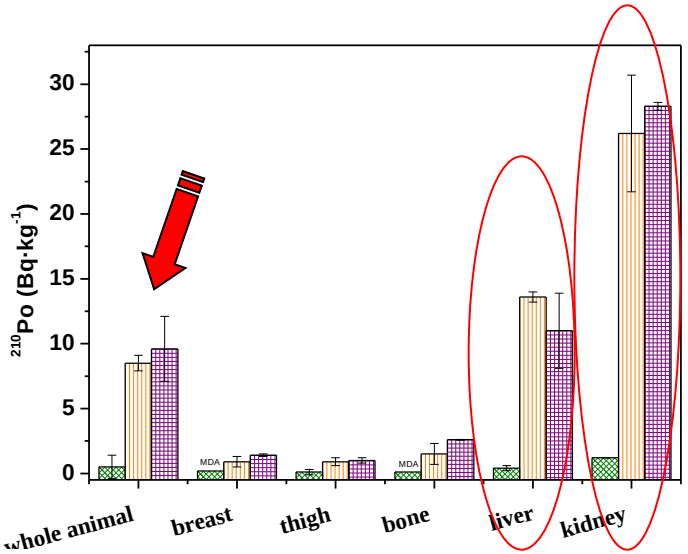
^{210}Po

RESULTS

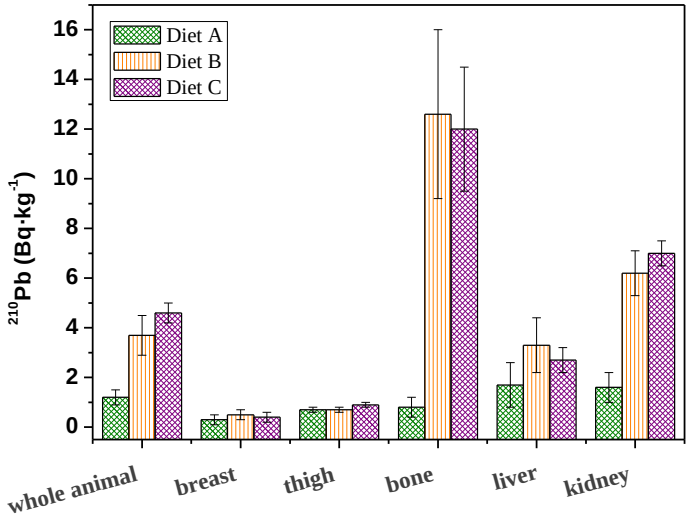
Accumulation of ^{210}Pb and ^{210}Po in broilers

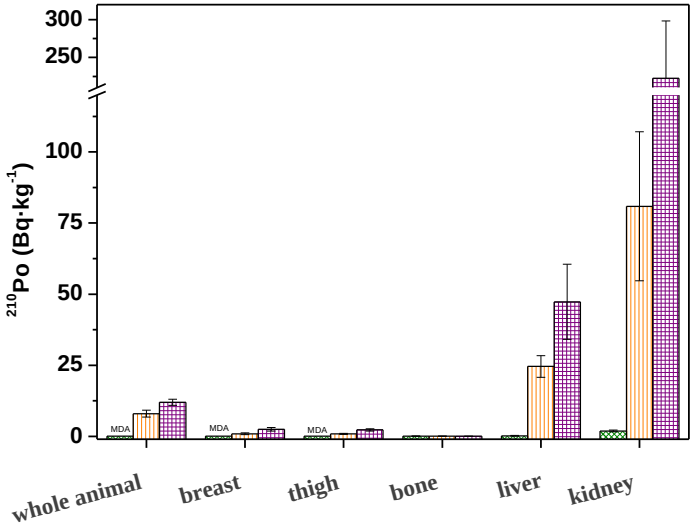
21 days feeding





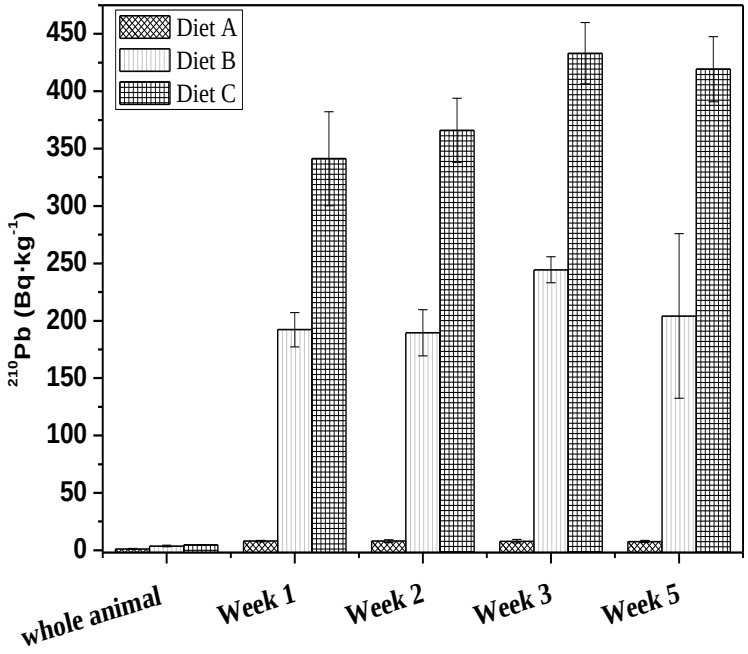
42 days feeding

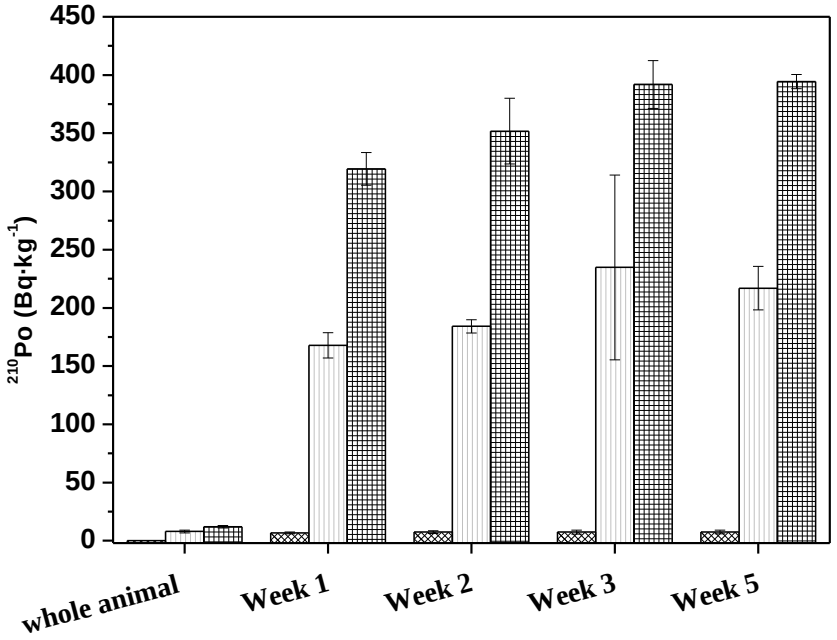




RESULTS

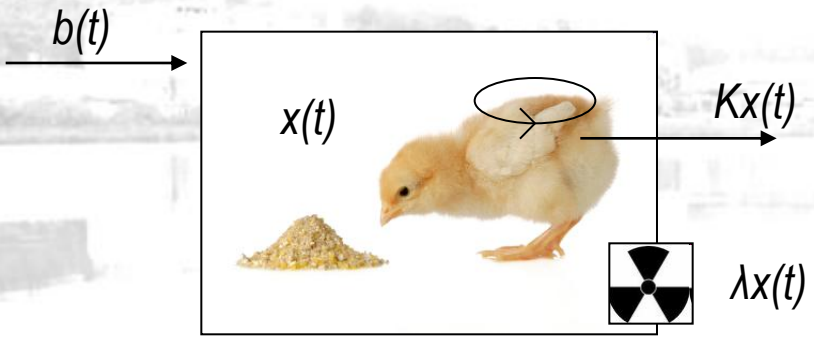
Accumulation of ^{210}Pb and ^{210}Po in feaces





Biokinetic model : first order approach

Single-compartment model: STEADY STATE CONDITIONS



$$\frac{d}{dt}x(t) = -\lambda x(t) - Kx(t) + b(t)$$

x(t) **specific activity of ^{210}Pb and ^{210}Po into the chicken body (whole animal);**

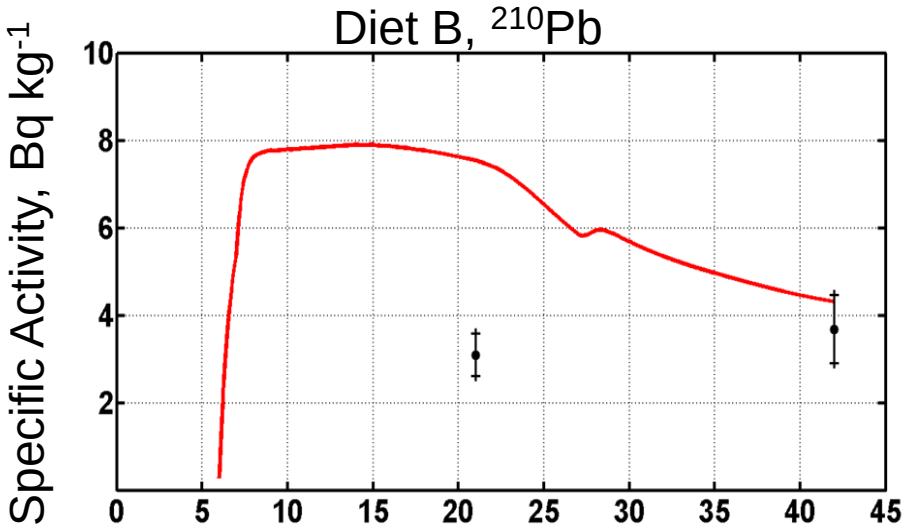
b(t) **input of ^{210}Pb and ^{210}Po to the chicken;**

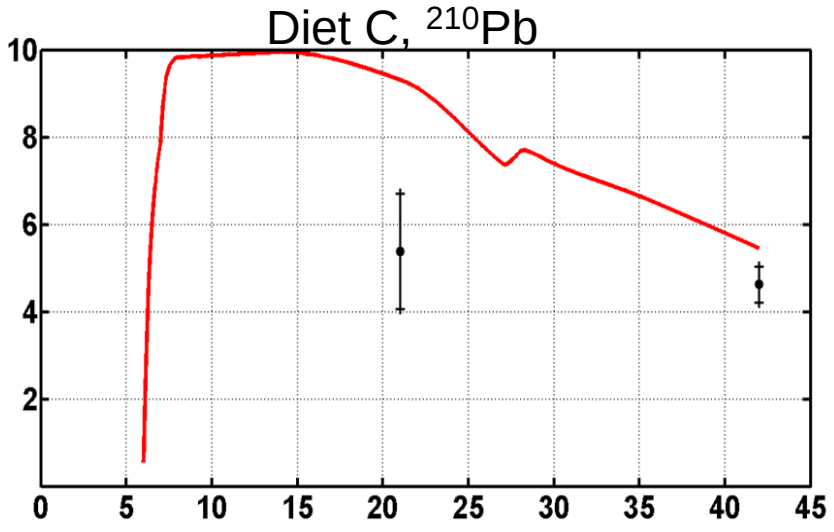
Kx(t) **output rate of ^{210}Pb and ^{210}Po;**

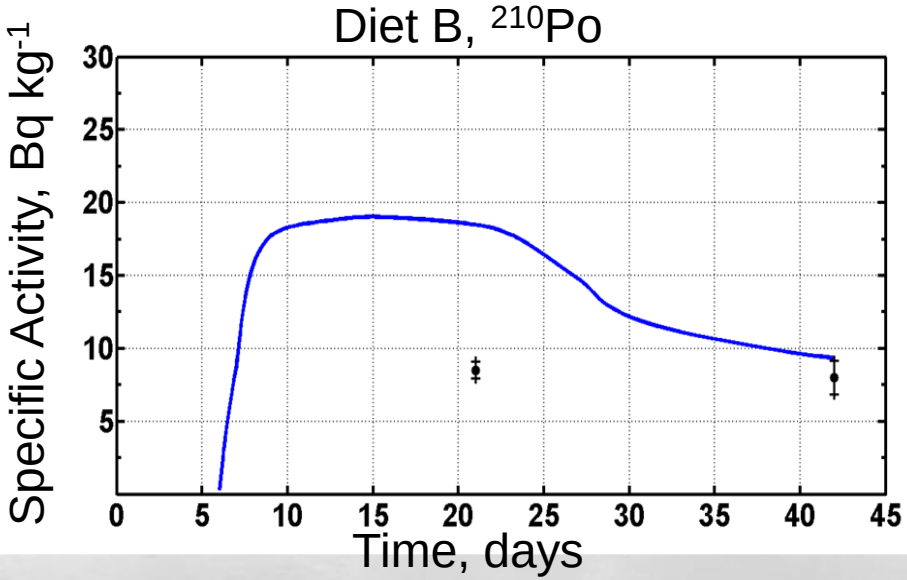
λx(t) **radioactive decay (also includes ^{210}Po ingrowth from ^{210}Pb decay)**

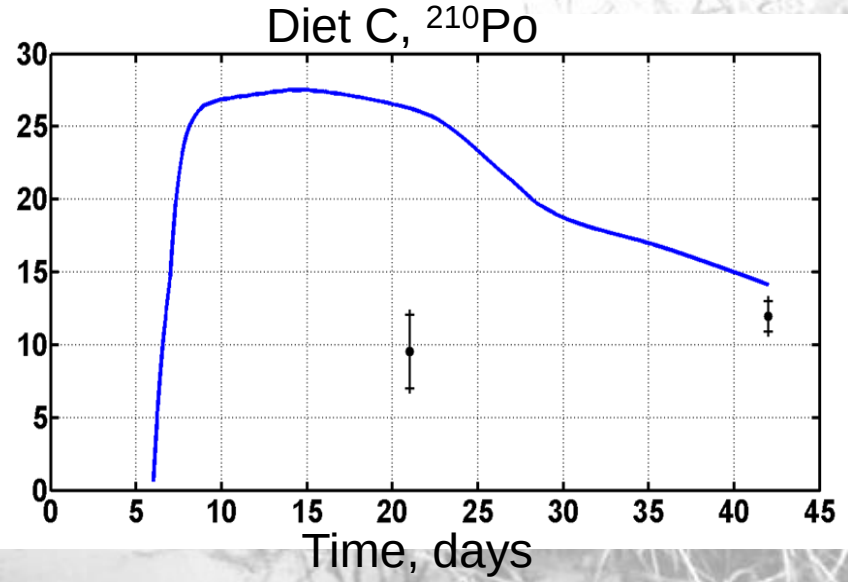
RESULTS

First order model results: whole animal





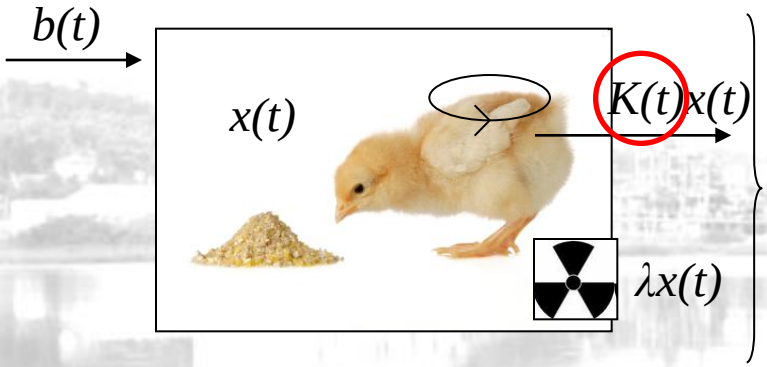




RESULTS

Biokinetic model: non-linear approach

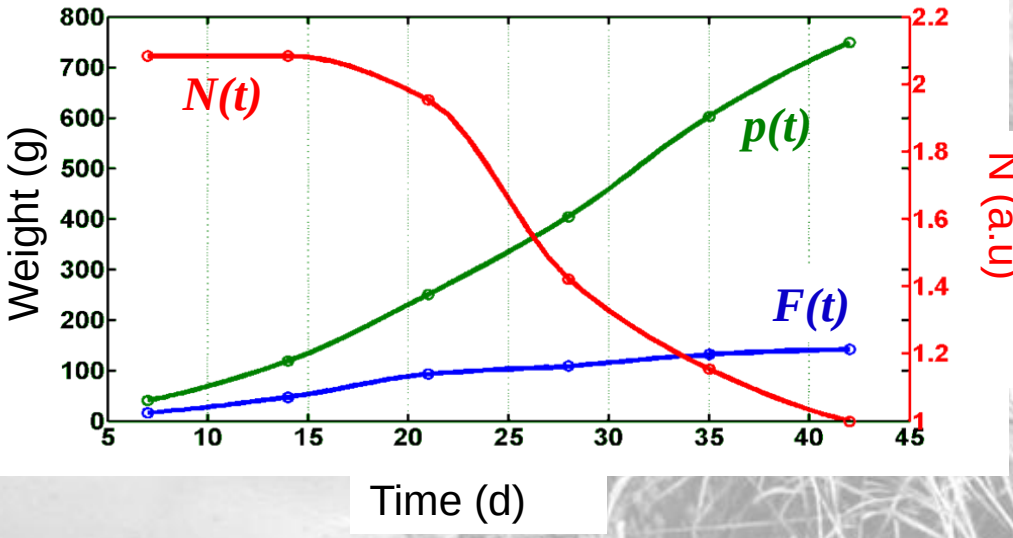
Single-compartment model: NON STATIONARY CONDITIONS



$$\frac{d}{dt}[x(t)p(t)] = -\lambda x(t)p(t) - k(t)x(t)p(t) + b(t) + x(t)\frac{d}{dt}p(t)$$

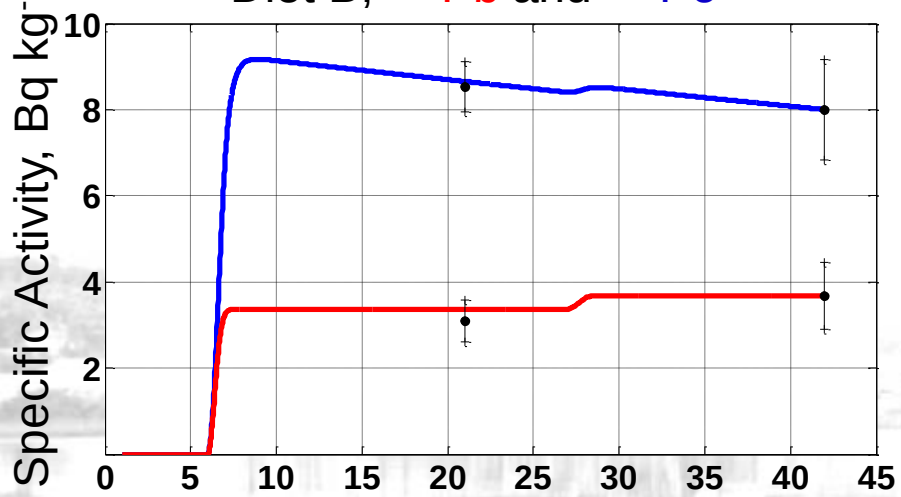
$$K(t) \doteq \bar{k}_x \frac{F(t)}{p(t)} \frac{\bar{p}}{\bar{F}} \doteq \bar{k}_x N(t)$$

- ***F(t)*** **food weight**
- ***p(t)*** **animal weight**
- $\bar{k}_x$ **transfer rate at stationary state**
- $\bar{F}$ **food weight at stationary state**
- $\bar{p}$ **animal weight at stationary state**

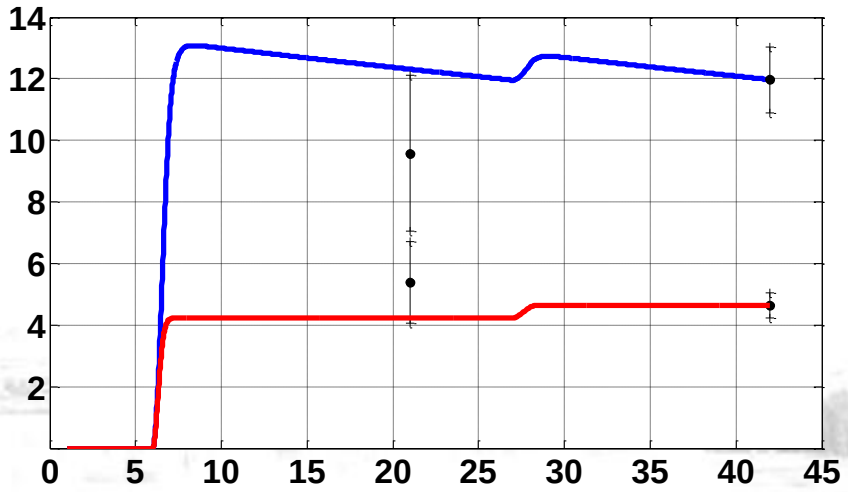


RESULTS

Diet B, ^{210}Pb and ^{210}Po



Diet C, ^{210}Pb and ^{210}Po



K (^{210}Pb) = 3.20 ± 0.41

K (^{210}Po) = 1.26 ± 0.06

K=[d^{-1}]

K (^{210}Pb) = 4.65 ± 0.61

K (^{210}Po) = 1.84 ± 0.25

CONCLUSIONS II

Conclusions: fluxes of radionuclides in DCP industrial process

- About $30 \cdot 10^3$ kBq·h^{-1} of ^{238}U, ^{230}Th, ^{226}Ra, ^{210}Pb and ^{210}Po enter the production system.
  - ^{238}U out-fluxes are divided between sludges and DCP.
  - ^{230}Th and ^{210}Po are discharged in sludges.
  - ^{226}Ra is mainly eluted through water effluents.

- Limits of radionuclides established in the new BSS are 1kBq·kg^{-1}. DCP industries are not exempted.
  - > 10^3 Bq·kg^{-1} of ^{238}U
  - > 10^4 Bq·kg^{-1} of ^{230}Th and ^{210}Po
  - > $2 \cdot 10^3$ Bq·kg^{-1} of ^{210}Pb
  - ^{226}Ra?

Conclusions: ^{210}Pb and ^{210}Po in chicken

- **^{210}Pb and ^{210}Po are accumulated in chicken tissues proportional to the initial contents in diets.**
  - **^{210}Pb accumulates in bones**
  - **^{210}Po accumulates in liver and kidneys**
  - **Accumulation is small compared to the amounts excreted.**

- **First order kinetic approach model would not fit the experimental data due to the fact that the model does not take into account the growing conditions of the organism.**

- **A model based on a non-stationary based function is capable to model the experimental results when growing conditions occur. Allows calculation of transfer rates *k* useful for first-order models if extrapolating *k(t)* when *t* tends to a steady state.**

Thank you!

Fluxes of the ^{238}U series within the Dicalcium Phosphate industrial production and the biokinetical analysis of ^{210}Pb and ^{210}Po in broilers due to its ingestion

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