Supplementary information (SI)

App.ix 1. Data ratio analysis

First, the concentrations in goat and chicken cartilages were expressed as C_{LT} and C_{LN} (µg.g^{-1} d.w.), respectively. Similarly, the concentrations in goat and chicken bones were expressed as CB_T and CB_N (µg.g^{-1} d.w.), respectively. The amount of lead in tissue (A_i) was calculated as the product of the concentration of lead in tissue (C_i) (µg.g^{-1}) and the dry weight of the individual organ (W) (g).

$$A_i = C_i \times W_i \qquad \text{(Eq.1)}$$

where C_i is the concentration of lead in cartilage (C_L), or bone (C_B) and W is the dry weight of cartilage (W_L) or bone (W_B). The total amount of lead in CB (A_X) is calculated as

$$A_X = A_L + A_B \qquad \text{(Eq.2)}$$

where A_L and A_B as described previously. The cartilage to bone amount ratio of lead (AR) is determined as

$$AR = A_L/A_B \qquad \text{(Eq.3)}$$

and the linear relationship between the amount and concentration of lead in bone can be determined in a simple linear form as written in Eq.4, where m and n are constants.

$$A_B = mC_B + \text{n} \qquad \text{(Eq.4)}$$

In the second part, the concentration ratios in the DRA consisted of cartilage to bone concentration ratio or simply concentration ratio (CR); cartilage to other tissue concentration ratio (COR); bone to other tissue concentration ratio (BOR); cartilage to cartilage concentration ratio (CCR) and bone to bone concentration ratio (BBR). The CR is defined as

$$CR = C_L/C_B \qquad \text{(Eq.5)}$$

where C_L is the concentration of lead in cartilage (µg.g^{-1} d.w.), and C_B is the concentration of lead in bone (µg.g^{-1} d.w.). The ratio of lead concentration in cartilage to that in other tissue (COR) can be defined as

$$COR = C_L/C_O \qquad \text{(Eq.6)}$$

where C_O is the concentration of lead in tissues other than CB, such as meat, trachea, teeth, and feather.

$$BOR = C_B/C_O \quad \text{(Eq.7)}$$

Cartilage to cartilage concentration ratio (CCR) can be defined as the ratio of lead concentration in cartilage to that in cartilage of tibia of the same individual.

$$CCR= C_L/C_L^{tib} \quad \text{(Eq.8)}$$

Similar to the CR, bone to bone concentration ratio (BBR) can be defined as the ratio of lead concentration in bone to that in tibia's bone of goat or chicken. The reference organ proposed was tibia in goat (Taguchi and Lopez 2020; Cretacci andParsons 2010). The BBR is calculated as,

$$BBR = C_B/C_B^{tib} \quad \text{(Eq.9)}$$

Variability ratio (VR) in DRA consists of variability ratio (VR), coefficient of variation (CV), and coefficient of variation ratio (CVR). VR can be defined as the ratio of two standard deviations (Pelabon *et al.,* 2020) which are variations between the standard deviation (s) of concentration of lead in cartilage to that in bone.

$$VR = s_L/s_B \quad \text{(Eq.10)}$$

The CV is determined as the ratio between standard deviation of a mean of the concentration of lead (s) to the mean of the concentration ($\bar{x}$), multiplied by 100%,

$$CV = (s/\bar{x}) \times 100\% \quad \text{(Eq.11)}$$

Variations are not only limited to variations of the concentrations but can also be developed as the ratio of CVs between two concentration ratios (CVR) (Dhanoa *et al.* 2018). The CVR is the ratio of two CVs, namely the ratio of CV of lead in cartilage (CV_L) to that in bone (CV_B),

$$CVR = CV_L/CV_B \quad \text{(Eq.12)}$$

Ratio of coefficient ratio (both for concentration and amounts) in logarithmic scale were used to estimate the relative average values of two groups and examine the relative variability of the two groups (Senior *et al.,* 2020). In this study, analysis of variability ratios (VR and CVR), was plotted in logarithmic scale (Eq.13) with regression passing the point of origin with constant slope value "a".

$$Ln\,VR = a\,Ln\,CVR \quad \text{(Eq.13)}$$

In the third part, the probability analysis in DRA consists of simple probability (SP), joint probability (JP) and conditional probability (CP). The SP as P (CR ≥ 1) and P (AR ≥ 1) was determined by using Monte Carlo simulation with 10,000 iterations

(Crystal Ball® software) (Decisioneering Inc., 2000). Having obtained P (CR ≥ 1) and P (AR ≥ 1) by Monte Carlo simulation, two types of probabilities which are joint probability (JP), and conditional probability (CP) were determined. The JP of (AR ≥ 1 $\cap CR \geq 1$), is determined as,

$$JP\ (AR\ \geq 1\ \cap CR\ \geq 1) = P\ (AR\ \geq 1)\ \times P\ (CR\ \geq\ 1) \qquad \text{(Eq.14)}$$

while the CP of AR ≥ 1 given CR ≥ 1 is defined as

$$CP\ (AR \geq 1\ |CR \geq 1) = \frac{P(AR \geq 1\ \cap CR \geq 1)}{P(CR \geq 1)} \qquad \text{(Eq.15)}$$

A quadrant analysis (QA) was developed, incorporating both JP and CP values, in which horizontal and vertical axes were assigned for P (CR ≥ 1) and P (AR ≥ 1), respectively.

Statistical analysis was performed by paired t – test (SPSS Inc., 2020). Evaluation of a set of data ratios (CR, AR, VR, CVR); linear relationships (A-C, AR-CR, and Ln VR – Ln CVR); and probabilities (JP, CP) of concentration and amounts of lead in a set of CBs as the main organs of accumulation is important to evaluate variability in exposure analysis of lead.

App.2. Estimation of whole-body burden of Pb in goat based on Pb concentration in tibia

Based on amount of individual cartilage and bones in this study (Table 2), the total HRFT in goat bone for both right and left sides could be determined as

$$2 \times (A_{BT}^{HRFT}) \qquad \text{(Eq.16)}$$

Based on Alkass et al. (2004) carcass weight of HRFT was 39.8% of whole carcass (w/w), and (A_{BT}^{HRFT}) 559.3 µg (this study; Table 2), the estimated cumulative dose of Pb in carcass (A_{BT}^{CW}) can be determined as

$$(A_{BT}^{CW}) = (100/\%HRFT) \times 2\, A_{BT}^{HRFT} \qquad \text{(Eq.17)}$$

= (100/39.8) × (2 ×559.3 µg)

= 2,810 µg.

By using the equation from Mawardi et al. (2018),

Carcass Weight = 1.884 + 0.53 Body Weight (Eq.18)

or by rearrangement

Body weight = 1.8 Carcass Weight (Eq.19)

The estimated whole body burden of lead in goat in this study (A_{BT}^{BW}) can be written as

$$(A_{BT}^{BW}) = 1.8\ (A_{BT}^{CW}) \qquad \text{(Eq.20)}$$

= 1.8 × 2,810 µg = 5,060 µg

Finally, by using the equation between lead concentration in tibia bone (C_{BT}^{tib}) (µg.g^{-1}) and cumulative dose (A_{BT}^{cp}) (g) from Cretacci and Parsons (2010),

$$C_{BT}^{tib} = 0.82\ (A_{BT}^{cp}) - 0.80 \qquad \text{(Eq.21)}$$

the (A_{BT}^{cp}) or the estimated amount (body burden) of lead by using the C_{BT}^{tib} of 5.08 µg.g^{-1} in this study (Table 1), can be calculated as

$$5.08 = 0.82\ (A_{BT}^{cp}) - 0.80 \qquad \text{(Eq.22)}$$

(A_{BT}^{cp}) = 3.37 g or 3,370 µg.

By comparing the calculated amount from HRFT in this study (5,060 µg) (A_{BT}^{BW}) to that estimated by a formula of Cretacci and Parsons (2010) (3,370 µg) (A_{BT}^{cp}) results in

$$A_{BT}^{BW} / A_{BT}^{cp} \qquad \text{(Eq.23)}$$

= 5,060 µg / 3,370 µg = 1.5

or the difference was less than by a factor of two.

Appendix 3. Estimation of whole body burden of lead in goat based on Pb concentration in teeth

Based on the equation in Bellis et al. (2008),

C_{ET} (µg.g^{-1}) = 1.2 A_{BT}^{bl}(g) + 1.0 (Eq.24)

and having known concentration of Pb in teeth in goat in this study (C_{ET}) (1.04 µg.g^{-1}) (Table 2), cumulative dose or body burden $\left(A_{BT}^{bl}\right)$ can be determined as 3.41 g or 3,410 µg.

Factor of difference between the estimated cumulative dose in this study (5,060 µg) (App.1) to that in Bellis et al. (2008) can be written as

$(A_{BT}^{BW})/\left(A_{BT}^{bl}\right)$ (Eq.25)

= 5,060 µg / 3,410 µg = 1.48

or the difference was less than by a factor of two

App. 4. Variability ratio (VR), coefficient of variation (CV), and coefficient of variation ratio (CVR) of lead in cartilage and bone of lead in animals in this study and literature

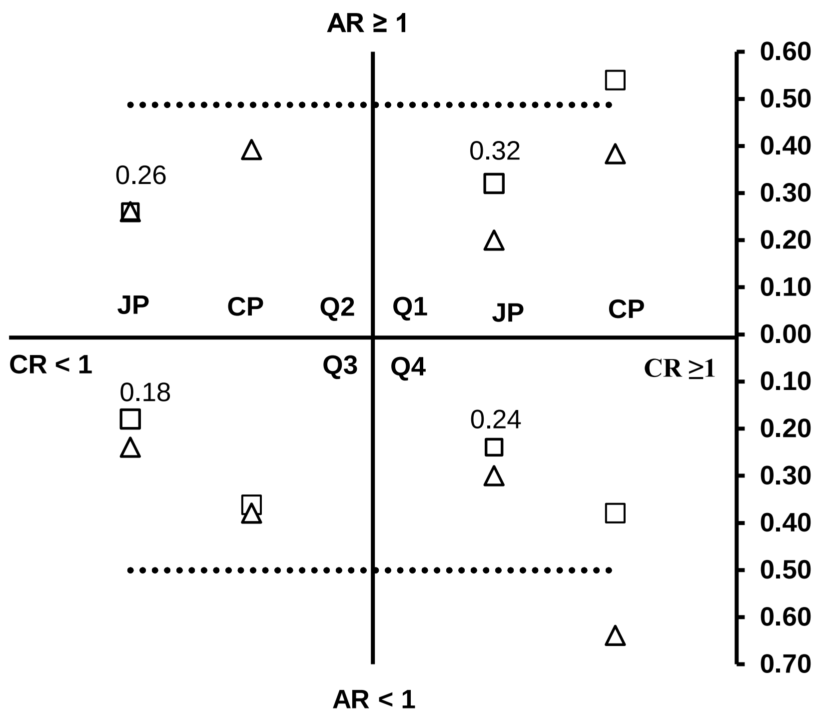
Organ	Animal	VR	$CV_L(\%)$	$CV_B(\%)$	CVR	Reference
Humerus (H)	Goat	0.34	9	26	0.34	Present study
	Goat		-	17[c]	-	Cretacci and Parsons, 2010
	Chicken	0.55	5	9	0.56	Present study
Radius (R)	Goat	0.58	6	10	0.60	Present study
	Goat		-	13[c]	-	Cretacci and Parsons, 2010
	Chicken	0.64	10	14	0.71	Present study
Femur (F)	Goat	1.03	7	6	1.17	Present study
	Goat		-	10[c]	-	Cretacci and Parsons 2010
	Red Fox	1.88	114	108	1.06	Lanocha et al., 2013
	Dog	2.04	110	110	1.00	Lanocha et al., 2013
	Red Fox	2.01	137	118	1.16	Lanocha et al., 2012[a]
	Dog	1.34	110	105	1.05	Lanocha et al., 2012[b]
	Chicken	0.84	9	10	0.90	Present study
Tibia (T)	Goat	1.04	6	6	1.00	Present study
	Goat		-	9[c]	-	Cretacci and Parsons, 2010
	Chicken	1.14	9	8	1.13	Present study
Non-specified	Chicken		16	11	1.44	Bratty et al., 2018
	Scaup[a]	1.93	169	94	1.80	Kalisinska et al., 2007
	Scaup[b]	2.82	103	91	1.13	Kalisinska et al., 2007
	Pochard[a]	1.57	109	84	1.29	Kalisinska et al., 2007
	Pochard[b]	6.98	115	65	1.77	Kalisinska et al., 2007

[a] Year 2000 [b] Year 2003 [c]left bone parts

App.5. Simple probability (SP), joint probability (JP), and conditional probability (CP) of amount ratio (AR) and concentration ratio (CR) of lead in cartilage and bones of goat and chicken

Simple Probability (SP)				Q	Joint Probability (JP) P (AR) ∩ (CR)		Conditional Probability (CP) P (AR | CR)	
P (AR)		P (CR)						
Symbol	P	Symbol	P		Symbol	P	Symbol	P
$P(AR_T \geq 1)$	0.58	$P(CR_T \geq 1)$	0.56	Q1	$P(AR_T \geq 1 \cap CR_T \geq 1)$	0.32	$P(AR_T \geq 1 \mid CR_T \geq 1)$	0.57
		$P(CR_T < 1)$	0.44	Q2	$P(AR_T \geq 1 \cap CR_T < 1)$	0.26	$P(AR_T \geq 1 \mid CR_T < 1)$	0.59
$P(AR_T < 1)$	0.42	$P(CR_T \geq 1)$	0.56	Q3	$P(AR_T < 1 \cap CR_T < 1)$	0.18	$P(AR_T < 1 \mid CR_T < 1)$	0.41
		$P(CR_T < 1)$	0.44	Q4	$P(AR_T < 1 \cap CR_T \geq 1)$	0.24	$P(AR_T < 1 \mid CR_T \geq 1)$	0.43
$P(AR_N \geq 1)$	0.46	$P(CR_N \geq 1)$	0.44	Q1	$P(AR_N \geq 1 \cap CR_N \geq 1)$	0.20	$P(AR_N \geq 1 \mid CR_N \geq 1)$	0.45
		$P(CR_N < 1)$	0.56	Q2	$P(AR_N \geq 1 \cap CR_N < 1)$	0.26	$P(AR_N \geq 1 \mid CR_N < 1)$	0.46
$P(AR_N < 1)$	0.54	$P(CR_N \geq 1)$	0.44	Q3	$P(AR_N < 1 \cap CR_N < 1)$	0.24	$P(AR_N < 1 \mid CR_N < 1)$	0.43
		$P(CR_N < 1)$	0.56	Q4	$P(AR_N < 1 \cap CR_N \geq 1)$	0.30	$P(AR_N < 1 \mid CR_N \geq 1)$	0.68

App.6. Quadrant Analysis (QA) of joint probability (JP) and conditional probability (CP) of cartilage to amount ratio (AR) and concentration ratio (CR) of lead in cartilage and bones of goat and chicken



Probabilities are visualized in four quadrants (Qs). Scales of probability values of JP and CP are provided in the right vertical axis. Legends square and triangle refer to goat and chicken, respectively. Dotted lines refer to CP value of 0.5.

App.7. List of Symbols

Symbol	Description	Eq. No.	Unit
A_B	amount of lead in bone	2	µg
A_i	amount of lead in any tissue	1	µg
A_L	amounts of lead in cartilage	2	µg
AR	amount ratio	2	Unitless
A_{BT}^{bl}	estimated amount (body burden) of lead based on its concentration in goat teeth in Bellis *et al.* (2008)	24	µg
A_{BT}^{HRFT}	estimated amount (body burden) of lead based on its amount in goat HRFT bones in this study	16	µg
A_{BT}^{cp}	estimated amount (body burden) of lead based on its concentration in goat tibia bone in Cretacci & Parsons (2010)	21	µg
A_{BT}^{BW}	estimated amount (body burden) of lead in body weight in goat	20	µg
A_{BT}^{CW}	estimated amount (body burden) of lead in carcass weight in goat	17	µg
A_X	total amount of lead in cartilage and bone	2	µg
BBR	bone (HRFT) to bone (tibia) concentration ratio	9	Unitless
BOR	bone to other tissue concentration ratio	7	Unitless
C_B	concentration of lead in bone	5	$µg.g^{-1}$ d.w.
C_{ET}	concentration of lead in teeth of goat	24	$µg.g^{-1}$ d.w.
C_B^{tib}	concentration of lead in the tibia bone	9	$µg.g^{-1}$ d.w.
C_{BT}^{tib}	concentration of lead in the tibia bone of goat	21	$µg.g^{-1}$ d.w.
C_i	concentration of lead in any tissue	1	$µg.g^{-1}$ d.w.
C_L	concentration of lead in cartilage	5	$µg.g^{-1}$ d.w.
C_O	concentration of lead in tissue other than cartilage or bone	6	$µg.g^{-1}$ d.w.
C_L^{tib}	concentration of lead in cartilage of tibia	8	$µg.g^{-1}$ d.w.
CB	cartilage and bone	-	-
COR	cartilage to other tissue concentration ratio	6	Unitless
CP	conditional probability	15	-
CR	concentration ratio	5	Unitless
CCR	cartilage (HRFT) to cartilage (tibia) concentration ratio	8	Unitless
CV	coefficient of variation	11	%
CV_B	coefficient of variation in bone	12	%
CV_L	coefficient of variation in cartilage	12	%
CVR	coefficient variation ratio	12	Unitless
DRA	data ratio analysis	-	-
HRFT	humerus, radius, femur, tibia	-	-

JP	joint probability	14	-
LADD	lifetime average daily dose	-	($\mu g.kg^{-1}$ body wt.day^{-1})
$_N$ (subscript)	chicken (e.g. CR_N)	-	
P (AR)	simple probability of amount ratio	14	Unitless
P (CR)	simple probability of concentration ratio	14	Unitless
P (AR ❙ CR)	conditional probability of amount ratio given concentration ratio	15	Unitless
P (AR ∩ CR)	joint probability of amount ratio and concentration ratio	14	Unitless
Q	Quadrant	-	-
QA	quadrant analysis	-	-
S	standard deviation of mean of concentration	11	$\mu g.g^{-1}$ d.w.
s_B	standard deviation of mean of concentration in bone	10	$\mu g.g^{-1}$ d.w.
s_L	standard deviation of mean of concentration in cartilage	10	$\mu g.g^{-1}$ d.w.
$_T$ (subscript)	goat (e.g. CR_T)	-	-
VR	variability ratio	10	Unitless
W_i	dry weight of organ	1	g (d.w.)
$\bar{x}$	mean of concentration	11	$\mu g.g^{-1}$
Equations 1-15;16-23; and 24-25 are provided in Apps. 1,2, and 3, respectively			