URANIUM IN DRINKING WATER: IMPACT ON URANIUM BONE CONTENT

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Introduction

Uranium is present at trace levels in the environment as a result of its primordial origin and the long half-lives of its radioisotopes. Due to its omnipresence in nature, uranium enters the food chain and eventually gets deposited into bones. Recently, Larivière *et al.* [1] have shown that the concentration of uranium in vertebrae is related to the calcium turn-over rate. This relationship indicates that the uranium level in bone represents the actual uranium consumption. Therefore, it is possible to assume that there would be a positive correlation between the source of ingestion and the uranium content of bone. As water has been shown to be a significant source of uranium [2], it will be used as an intake source indicator.

Materials and Methods

The Canadian Radiological Monitoring Network had collected over 5,000 human bone samples during the 1950's to the 1980's. The bone samples were originally collected to monitor and assess the impact of nuclear tests on human health, by measuring their ^{90}Sr content. This archive is unique since, in addition to the sample itself, it contains partial information on the age, sex, time and cause of death, and residence of the donor. A total of 71 samples were measured from seven western Canada locations: Victoria (BC), Vancouver (BC), Edmonton (AB), Calgary (AB), Saskatoon (SK), Regina (SK), and Winnipeg (MB) [Figure 1]. Only vertebrae bones have been used in this experiment in order to reduce the fluctuations resulting from variation in U retention in different skeletal parts. In addition, bone from a specific age group (11-30y, geometric average: 18.6y) were used in this study to minimize the impact of age on the U concentration.

Samples were dissolved using micro-wave digestion following a procedure described elsewhere [1]. NIST-4356 (Bone Ash – Radioactivity) was used for QA/QC. Measurements were performed using a sector-field inductively coupled plasma mass spectrometer (ICP-SFMS, ThermoFinnigan Element2) with an Apex HF high-sensitivity inlet system (Elemental Scientific Inc) as nebulization system.

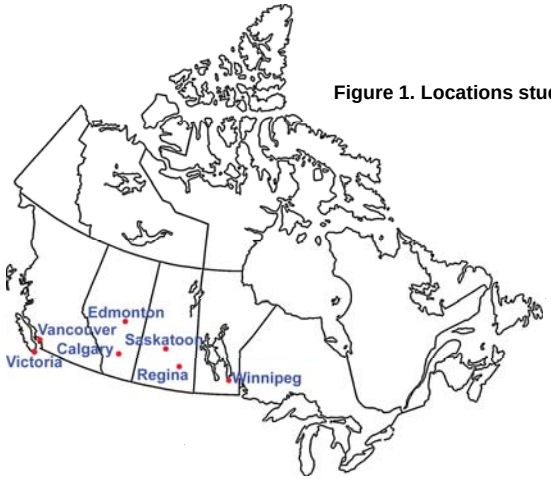


Figure 1. Locations studied

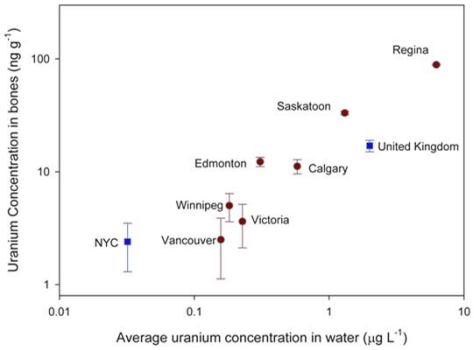
Results

Table 1. Geometric averages for U bone and water analysis

Location	Number of samples measured	$[U]_{Bone\ Ash}$ (ng g^{-1})	$[U]_{Drinking\ Water}$ (average, µg L^{-1})
Victoria (BC)	9	3.6 ± 1.5	0.22
Vancouver (BC)	24	2.5 ± 1.4	0.16
Edmonton (AB)	6	12.3 ± 1.2	0.31
Calgary (AB)	5	11.2 ± 1.6	0.57
Saskatoon (SK)	3	33.1 ± 1.2	1.30
Regina (SK)	12	88.7 ± 1.4	6.23
Winnipeg (MB)	12	5.0 ± 1.4	0.18
New York City[a]	63	2.4 ± 1.1 [3]	0.032 [4]
United Kingdom[a]	12	17 ± 2 [5]	2 [6]

[a] All age groups included

Figure 2. Variation in uranium content of bone as a function of average drinking water concentration



Modeling of data using Integrated Modules for Bioassay Analysis (IMBA) software

In order to understand how $[U]_{water}$ and $[U]_{bone}$ are correlated, modeling with IMBA was performed from age 0 to 19. The daily uranium consumption [U_T, in µg d^{-1}] was calculated for each age group using the following equation:

$$(1) \quad U_T = U_F \times m + U_W \times d$$

where U_F, the daily intake of uranium per body weight from food (µg kg^{-1} d^{-1}), m, the body weight (kg), U_W, the uranium concentration in water (µg L^{-1}), and d, the daily water consumption (L d^{-1}). Intakes from inhalation were considered marginal and were not included in the calculations. Total daily intakes were subsequently converted into Bq d^{-1} and the activity in the skeleton determined at age 19.

Figure 3. Comparison between experimental data and IMBA modeling

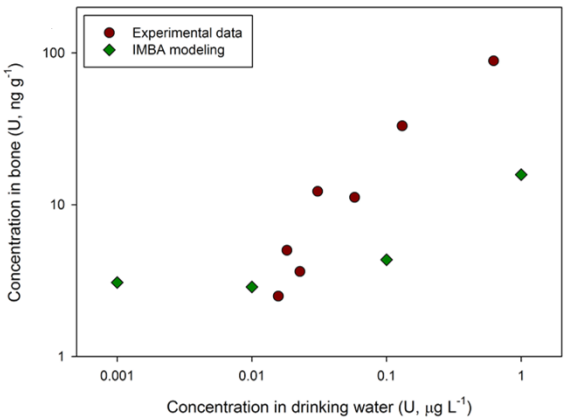


Table 2. Averaged data used for the uranium intake modeling in IMBA

	U_T (Bq d^{-1})[a]				
Age group	U_W = 0[b]	U_W = 0.01	U_W = 0.1	U_W = 1	U_W = 10
0-2	0,0254	0,0256	0,0270	0,0408	0,1796
2-4	0,0391	0,0393	0,0407	0,0545	0,1933
4-6	0,0433	0,0435	0,0455	0,0653	0,2631
6-8	0,0433	0,0435	0,0461	0,0721	0,3313
8-10	0,0555	0,0558	0,0584	0,0844	0,3436
10-12	0,0670	0,0673	0,0699	0,0958	0,3551
12-14	0,0602	0,0605	0,0631	0,0890	0,3483
14-16	0,0736	0,0739	0,0765	0,1024	0,3617
16-18	0,0915	0,0918	0,0944	0,1203	0,3795
18-20	0,0961	0,0964	0,0996	0,1310	0,4448

[a] converted in Bq d^{-1} from µg d^{-1} using the following ratio: 25.27 Bq mg^{-1}
[b] drinking water concentration of uranium in µg L^{-1}

Conclusions

- An increase in $[U]_{water}$ does result in an increase in $[U]_{bone}$ through modeling, but not to the extent that was measured experimentally.
- At low $[U]_{water}$ concentration, the experimental data and the model are consistent.
- Discrepancies at higher $[U]_{water}$ could be explained by the fact that food intake used in the calculation are based on 2000-2003 National Total Diet Studies that do not necessarily represent the food intakes from the 50-80's. As more local food was consumed back then, $[U]_{water}$ could have impacted $[U]_{food}$ to a larger extent that originally believed.

References

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