Abstract The natural uranium concentration in the potable water in Argentina is analyzed taking into account the new uranium metabolic model and assuming a new toxicological limit for member of the public. The chemical toxicity of uranium in the kidney is clearly demonstrated by a large amount of published data, and there is an actual tendency towards the diminution of the old threshold of 3 µg/g for the renal toxicity for member of the public. Meanwhile, probabilistic analyses show that applications of safety factor to each parameter in a deterministic analysis yield a final risk overestimate. The kidney burden for chronic ingestion is determined accordingly parameters fix by the new metabolic model for uranium. The analysis is carries out with a toxicological limit for the public of 0.15 µg/g of kidney. We propose it based on applying the factor 1/20 to the limit for workers of 3 µg/g. It is of interest to determine whether limits on intakes of uranium derived from limits on radiation dose provide protection against chemical toxicity in the kidney. The chronic ingestion given by the toxicological limit proposed, reveals that the annual effective dose limit of 1 mSv to radiological risk for the public is not exceed. The analysis confirmed that the chemical toxicity should be considered in developing health protection standard for the public for chronic ingestion of natural uranium in soluble form. The level of natural uranium in potable water in Argentina is well below respect to the value corresponding to the toxicological limit proposed. So, It is possible satisfy a safety factor to drinking water levels in agreement with the international recommendations. The probabilistic approach as a means to a more realistic understanding of the toxic risk of uranium ingestion demonstrates that these background levels in water constitute a low risk.
1. Introduction

The chemical toxicity of uranium in the kidney was clearly demonstrated by a large amount of data on uranium in animals and humans [1] y [2]. It was of interest to determine whether limits on intakes of uranium derived from limits on radiation doses provide protection against chemical toxicity in the kidney.

This question became more relevant since the traditional threshold concentration for toxicity in the kidney, 3 µg/g of kidney, is being discussed and the assumed safety factor for limiting the kidney concentration for member of the public to levels below the threshold was increased.

The analysis was mainly based on the relationship between kidney burden and radiation dose from chronic ingestion of soluble uranium. The parameters presented in the metabolic model of ICRP 69 [3] were included and a proposed toxicological limit for concentration of uranium in the kidney jointly the current limit on radiation dose to public was used to perform this relationship.

The trend in the literature has been assumed that the older occupational limit on the toxic threshold for concentration of uranium in the kidney is too high for use for estimating risk to the general public. The uses of conservative estimates in analyses design to protect public health is well establish. There is a negative side to this approach however. Reducing exposure more than necessary is not in the public interest for it consumes resources that could be better used elsewhere. Applying safety factors to each parameter in a deterministic analysis yield a final risk estimate that overestimates risk by an unknown amount. While the analysis is primarily a scientific task, size of the safety factor is a political decision. Probabilistic analysis, [4] explicitly estimates the uncertainty and allows political decision-makers and the public understands the degree of safety associated with a given situation. A range of 0.1 to 1.0 µg/g of kidney from expert’s opinion appeared appropriated for public, which does not have the additional protection of routine medical surveillance and bioassay. The analysis on this paper adopted a value of 0.15 µg/g of kidney consistent with the expert’s opinion above mentioned.

2. Analysis Description

Given the knowledge of the chemical toxicity of uranium in the kidney and proposals that a safety factor of at least 10 below an assumed threshold for toxicity should be applied in limiting kidney burdens for members of the public, it is studied whether current standard for limiting radiation dose to the public would provide adequate protection against chemical toxicity if the dose were due entirely to ingestion of uranium. The recommended metabolic and dosimetric models from ICRP are used to obtain annual effective dose and concentration of uranium in the kidney at steady state from chronic ingestion of soluble uranium by adults.

The relationship between uranium in the kidney and radiation dose was established through the following steps:

1- The concentration in the kidney per unit mass intake rate at steady state for ICRP model was obtained based on parameters presented in Table I.
Table I: ICRP models parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>ICRP 30</th>
<th>ICRP 69</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI uptake Fraction (f1)</td>
<td>0.05</td>
<td>0.02</td>
</tr>
<tr>
<td>Deposition fraction/Retention half-times kidney</td>
<td>0.12 / 6 d</td>
<td>0.12 / 7 d</td>
</tr>
<tr>
<td>Deposition fraction/Retention half-times kidney</td>
<td>0.00052 / 1500 d</td>
<td>0.00052 / 1500 d</td>
</tr>
</tbody>
</table>

The adopted absorbed fraction through the gut to bloodstream agrees with a conservative approach since several studies reveals a range from 0.005 to 0.05.

It was appropriated to take account that the nephrotoxic risk based on a conservative analysis, where exposure variables and model parameters are point values, was overestimated compare with a probabilistic approach, in which the uncertainties are expressed as a probability distribution, as a means to a more realistic understanding of the nephrotoxic effect. The retention fraction in the kidney due to chronic ingestion of soluble uranium was plotted and it is showed in the Fig 1.

The analysis assumed a nephrotoxic limit of 0.15 µg/g of kidney based on applying the 1/20 factor to traditional nephrotoxic limit for workers. This factor was applied in ICRP publication N° 60 [5] to obtain the annual effective dose limit for public of 1 mSv, from the recommended limit of 20 mSv for workers. The ICRP 30 metabolic model included in the CINDY code [6] was modified accordingly the parameters adopted in the new metabolic model given in the ICRP publication 69.

*FIG. 1. Kidney burden from chronic ingestion of uranium (1µg/d)*
2- the chronic intake that determines the limit of uranium concentration in the kidney was performed. The assessment was based on obtaining the kidney burden due to a chronic intake of uranium of 1 µg/day taking into account the 310 g of two kidneys and the limit of 0.15 µg/g of kidney.

3- The effective dose due to the chronic intake that determines the nephrotoxic limit was assessed taking into account: a) The kidney concentrations at steady state from chronic ingestion of soluble uranium by adults b) The ingestion is expected to give the highest kidney burden per unit effective dose for any mode of intake and c) at steady state the annual radiation dose per unit rate of intake is the same as the committed dose per unit intake [7].

### 3. Results

The kidney burden was estimated including the biokinetics parameters from the ICRP 69 metabolic model and as it was shown in the figure I, the kidney burden reached a constant value of 0.025 µg per unit chronic intake, since time 50 up to 300 days. The threshold value for kidney damage of 0.15 µg/g of kidney taking into account the 310 g of two kidneys was equal to 46.5 µg. The chronic intake of uranium that implies to reach the toxic limit was estimated on 1.86 mg/day. The chronic ingestion of 1.86 mg/day, considering specific activity of natural uranium, 25 Bq/mg, resulted in a daily intake of 46.5 Bq. The effective dose coefficient was estimated accordingly isotopic composition for $^{238}$U $^{234}$U $^{235}$U in natural uranium and the values given by the ICRP publication N 0 72 [8], obtaining the effective dose coefficient per unit activity of 4.67E-8 Sv/Bq.

At steady state the annual radiation dose per unit rate of intake was considered the same as the annual committed dose per unit intake. The intake of 46.5 Bq/day through 365 days resulted in an annual intake of 1.7E4 Bq. The annual effective dose due to an intake rate that results in the kidney concentration of the threshold of 0.15 µg/day was estimated in 0.79 mSv (< 1 mSv).

Accordingly the uranium levels monitored in drinking water in our country [9], the maximum concentration measured was below 10 µg/l (one order of magnitude below the 100 µg/l recommended by US Environmental Protection Agency). Assuming that the ingestion of drinking water is the main mode of intake of uranium by the members of the public, this analysis showed that a concentration of 930 µg/l in drinking water would determine to reach the nephrotoxic threshold.

### 4. Conclusion

This paper presented an analysis of the relationship between kidney burden and effective dose for chronic ingestion of soluble uranium by adults based on an assumed threshold concentration of uranium in the kidney for chemical toxicity of 0.15 µg/g of kidney. The conclusion was that currents standard for limiting radiation exposure of the public did not provided adequate protection against chemical toxicity. It was demonstrated that the limit on effective dose of 1 mSv for chronic exposures of the public correspond to kidney concentration from ingestion of soluble uranium that exceed the value of 0.15 µg/g.

From the point of view that the threshold value for nephrotoxic effects should be described as a distribution rather than by a single conservative upper bound, the risk to adults of uranium toxicity at background levels in drinking water in Argentina would be in a better situation since the traditional conservative assessment was done.

### 5. References

1 Sullivan, MF *Absorption of Actinide elements from the gastrointestinal tract of rats guinea pigs and dogs* Health Phys 38: 159-171 1990
2 Spencer MH et al *Measures Intake and Excretion Patterns of Naturally Occurring $^{234}$U, $^{238}$U and Calcium in Humans*, Rad Res 124:90-95 1990


6 CINDY System Operation (*Code for Internal Dosimetry*), Canberra Industries Inc.

