A Review of the Document
"The Quantitative analysis of Uranium Isotopes in the population of Port Hope, Ontario Canada" authored by Durakovic, Gerdes, and Zimmerman

Prepared for the Municipality of Port Hope

by

Murray M. Finkelstein PhD MD CCFP

Program in Occupational Health and Environmental Medicine
McMaster University

and
The Departments of Family Medicine and Public Health Sciences
University of Toronto

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Executive Summary

This review of the document entitled "The Quantitative analysis of Uranium Isotopes in the population of Port Hope, Ontario Canada" authored by Durakovic, Gerdes, and Zimmerman (DGZ) was prepared at the request of the Municipality of Port Hope. The goal was to assess whether there are public health issues arising from the results of the study that require the attention of the authorities.

Uranium is present in soil, food and water throughout the world. In Port Hope there is also emission from industrial processes. The soluble portion of inhaled or ingested uranium moves into the blood, and then passes through the kidneys into the urine.

Uranium is a radioactive heavy metal with very low radioactivity. Its major toxicity is damage to the kidneys. DGZ report that they obtained urine samples from nine subjects who were residents of Port Hope. They present no detail about the subjects. In particular there is no mention of whether any of the subjects had occupational exposures to uranium. The urine samples were analysed by mass spectrometry to determine isotopic content. The results were presented in Tables 1 and 2 of their paper.

The authors report that the average concentration of uranium in the urine of the nine subjects was 8.1 ng/L. Expressed in a different way, this is 8 parts of uranium per million million parts of urine (or about 1 part uranium per 100 thousand million parts of urine). This tiny number is hard to conceptualize. The concentration is equivalent to dividing 1/3 of an aspirin tablet among all the citizens of Canada and having each swallow their piece of aspirin with a litre of water.

Is the presence of uranium at an average concentration of 8.1 ng/L more than one finds elsewhere in the world? DGZ state that they obtained control samples from residents of other parts of Ontario. In fact, there were only 2 control samples obtained, a number that is much too small to be helpful given the known variability of urine uranium measurements in individuals. I was unable to find reports of uranium sampling among other Canadians. Fortunately there are reports of measurements made elsewhere. Scientists from the US Centers for Disease Control reported the results of a survey of uranium in the urine of a nationally representative sample of 500 US residents. The average concentration of uranium in the urine of these 500 subjects was 11.0 ng/L. In Europe, urine samples were collected from 24 male and 14 female occupationally unexposed subjects, 20-50 years of age, living and working in the district of Rome, Italy. The mean concentration was 10 ng/L. The average result in Port Hope was thus *lower* than the average found in the United States and in Italy.

DGZ spend some time talking about depleted uranium. Most nuclear reactors (with the exception of the Candu) are designed to operate with above natural amounts of U^{235} in the core. Elaborate technology has been developed to separate this isotope from the chemically identical U^{238} which comprises over 99% of natural uranium. What is left behind is termed depleted uranium, that is, natural uranium with less than natural abundance of U^{235}. Depleted uranium is indistinguishable to the body from natural uranium. Removal of U^{235} makes depleted Uranium *less* radioactive than natural uranium. Since the decay energy of U^{235} is higher than that of U^{238}, the radioactive decays of depleted uranium are thus, on average, less energetic and less biologically damaging than those of natural uranium. One individual (Subject 3) had an isotopic ratio statistically significantly different from natural uranium, consistent with intake of depleted uranium. This individual thus has less U^{235} in their urine than the others. He/she would be thus expected to have fewer nuclear decays, and at a lower average decay energy, than subjects with the natural ratio of uranium in their bodies. It cannot be argued that this is harmful.

In conclusion, I have reviewed the report authored by Durakovic, Gerdes, and Zimmerman. The most important finding was that the average concentration of uranium in the urine of Port Hope residents, 8 ng/L, about 1 part uranium per 100 thousand million parts of urine, was similar to (actually less than) the average concentrations reported elsewhere in the world. I conclude that these results do not suggest any danger to the public health from uptake of uranium by residents of Port Hope.

Introduction

This review of the document entitled “The Quantitative analysis of Uranium Isotopes in the population of Port Hope, Ontario Canada” authored by Durakovic, Gerdes, and Zimmerman (DGZ) was prepared at the request of the Municipality of Port Hope. The goal was to assess whether there are public health issues arising from the results of the study that require the attention of the authorities.

By way of introduction, I am an occupational and environmental physician with 29 years of experience in issues of human exposure to chemical, physical, and radioactive agents. For many years I was the representative of the Province of Ontario on the Committee of Medical Advisers to the Atomic Energy Control Board. Prior to entering medical school, I obtained a PhD in experimental physics from Case-Western Reserve University in Cleveland, Ohio.

DGZ report that they obtained urine samples from subjects who were residents of Port Hope. They present no detail about the samples. I presume that these were “spot” random samples of varying volume and concentration. They mention control samples from residents of other parts of Ontario. In fact, there were only 2 control samples obtained. This is woefully inadequate given the known variability of urine uranium measurements in individuals. The samples were analysed by mass spectrometry to determine isotopic content. The results were presented in Tables 1 and 2 of their paper.

Uranium Isotopes

Before proceeding further it is useful to discuss uranium isotopes. Uranium appears in nature as a variety of species, differing by the number of neutrons in the atomic nucleus. The number of protons and electrons are identical among the various isotopes. The human body identifies atoms of uranium only by the number of electrons in the external shell, so as far as the human body is concerned, all uranium atoms are the same. Their metabolism and distribution in the human body is identical. They differ internally but are externally indistinguishable to the human body in their appearance, chemistry, *and* toxicity.

The isotopes of uranium are labelled by their atomic weight, that is the sum of the numbers of protons (fixed at 92) and neutrons (variable). The major isotopes are U^{238} (99.27% relative abundance in natural uranium), U^{235} (0.72% relative abundance), and U^{234} (0.005% relative abundance). There are several additional manmade isotopes which are produced in nuclear reactors, of which U^{236} is mentioned by DGZ.

Uranium is radioactive, that is, over time it will split into 2 smaller atoms by emitting particles of radiation or matter. Uranium is of very low radioactivity, a property measured by the “half-life”, the amount of time it takes for 50% of a sample of radioactive material to decay and change into something else. The shorter the half-life of ingested materials, the more the body will be bombarded by the emitted radiation. The longer the half life, the less frequent the bombardment. With the exception of the very rare U^{234} , all of the isotopes of uranium have half-lives exceeding *10 million years.* In comparison, the half life of radioactive iodine used by doctors to treat thyroid cancer is *8 days.*

The Table below gives the relative abundances and half-lives of the uranium isotopes.

Table 1: Relative abundances and half-lives of the uranium isotopes		
Isotope	Relative Abundance in Nature	Half-life (Years)
U^{238}	(99.27%)	4 thousand million years
U^{235}	(0.72%)	700 million years
U^{234}	(0.005%)	245000 years
U^{236}	Man made	23 million years

The potential to cause radiological harm is related to the decay energy of the emitted radiation. This is shown in Table 2 below. The decay energies of the isotopes are similar.

Table 2: Decay Energies of the uranium isotopes	
Isotope	Decay Energy (Millions of Electron Volts)
U^{238}	4.27
U^{235}	4.7
U^{234}	4.86
U^{236}	4.57

Depleted Uranium.

Most nuclear reactors (with the exception of the Candu) are designed to operate with above natural amounts of U^{235} in the core. Elaborate technology has been developed to separate this isotope from the chemically identical U^{238}. What is left behind is termed depleted uranium, that is natural uranium with less than natural abundance of U^{235}. Depleted uranium is indistinguishable to the body from natural uranium. Because U^{235} is an isotope whose half life is 6 times shorter than U^{238}, its removal makes depleted Uranium *less* radioactive than natural uranium. Since the decay energy of U^{235} is higher than that of U^{238}, the radioactive decays of depleted uranium are thus, on average, less energetic and biologically damaging than those of natural uranium.

The Concentration of Uranium in the Urine of Port Hope residents.

Uranium is a very common natural element, appearing in most soils in the world. It is present in foodstuffs and drinking water. It is thus ingested by everyone and appears as an excretion product in most people's urine. In Port Hope, there is the additional possibility of intake from uranium dusts emitted from industrial processes or wastes. This latter would be an inhalational pathway, and soluble compounds of uranium will be absorbed into the circulation and appear in the urine. It is not possible from urinalysis to identify the route(s) of exposure. The important consideration is that, because of its low radioactivity, the major toxicity of uranium is its potential "heavy metal" toxicity to the kidney. This potential can be well assessed by measurements of the concentration of uranium in urine.

Since uranium is ingested by everyone, it would be expected that it would be found in the urine of Port Hope residents. So, the important question is: Is the uranium concentration of the urine of Port Hope residents higher than *average?* DGZ present the results of analysis of 2 non-Port Hope residents, as "controls". Two comparison subjects is too few to be reliable as controls. DGZ report, for comparison purposes, that the total uranium concentrations in the urine of humans is 1- 7 ng/L. *This is incorrect.* I have been unable to locate survey values for Canadians, so I will use comparative values from American and European populations that have been published in the medical literature.

Firstly, I reprint in Table 3 below the results of the measurements of uranium in urine (ng/L) reported by DGZ.

Table 3. Uranium concentrations in the Urine of Port Hope residents reported by DGZ	
Subject	Urine concentration (ng/L)
1	8.5
2	24.8
3	7
4	5.1
5	2.7
6	9.4
7	8.8
8	3
9	3.7
AVERAGE	8.1 ng/L

The average concentration of uranium in the urine of the nine subjects was 8.1 ng/L. Expressed in a different way, this is 8 parts of uranium per million million parts of urine (or about 1 part uranium per 100 thousand million parts of urine). This tiny number is hard to conceptualize. This tiny number is hard to conceptualize. The concentration is equivalent to dividing 1/3 of an aspirin tablet among all the citizens of Canada and having each swallow their piece of aspirin with a litre of water.

Is the uranium concentration of the urine of Port Hope residents higher than *average?*

A. American Survey

Ting and colleagues, from the Centres for Disease Control (CDC) in Atlanta, published the results of a survey of uranium in the urine of 500 US residents (Ting et al. 1999). The Urine samples were collected as part of NHANES III, a nationally representative sample of the US population. The Table below gives the distribution of sample results.

Table 4: Percentile distribution of uranium concentrations in the urine of Americans (ng/L)						
5th percentile	25th percentile	50th percentile	75th percentile	90th percentile	95th percentile	AVERAGE
1.4 (ng/L)	3.8 (ng/L)	6.3 (ng/L)	11.8 (ng/L)	25.6 (ng/L)	34.5 (ng/L)	**11.0 (ng/L)**
Port Hope Comparison		Number of subjects (out of 9) with results at or less than US value				
	3/9 (33%)	4/9 (44%)	8/9 (89%)	9/9 (100%)		**8.1 ng/L**

Comparing the Port Hope results with the American survey, we find that the average concentration of Uranium in urine is lower than the US average, and that the distribution is shifted to the left, that is to lower concentrations.

Rome, Italy

Urine samples were collected from 24 male and 14 female occupationally unexposed subjects, 20-50 years of age, living and working in the district of Rome, Italy (Galletti et al. 2003). The mean concentration found was 10 ng/L, similar to the Port Hope result.

CONCLUSION on Uranium Excretion

Based upon the results presented by DGZ, it can be concluded that residents of Port Hope have urinary uranium concentrations similar to, or lower than, residents of the United States and Rome, Italy.

Depleted Uranium

DGZ have measured the isotopic ratios of uranium in the urine of the Port Hope residents. As seen in Table 1, natural uranium has more U^{238} than U^{235}: the ratio is 137.88:1. In any sample, if some of the U^{235} has been removed (depleted uranium) , then the ratio will increase above 137.88. DGZ present the results of the determination of this ratio in the Port Hope urine samples. Because there is statistical uncertainty about any measurement of radioactivity, they give the estimate with a measure of statistical uncertainty, the standard deviation (SD). From statistics theory, we know that on 100 repeated measurements of any of these samples, one would find 95 of them to lie between (Estimate - 2 sd) and (Estimate + 2 sd). Any result in which estimate ± 2 sd excludes 137.88 is said to be significantly different from the natural ratio. We thus see that only one sample (Subject 3) has an isotopic ratio statistically significantly different from natural uranium. This individual has less U^{235} in their urine than the others. He/she would be thus expected to have fewer nuclear decays, and at a lower average decay energy, than subjects with the natural ratio of uranium in their bodies. It cannot be argued that this is harmful.

U^{236}

U^{236} is a manmade isotope. It has a half-life of 23 million years and it's decay energy is slightly higher than that of U^{238}. Four subjects had detectable levels of U^{236} in their urine. The levels were about 1 millionth or less of the amount of U^{238}, that is the average concentration was about one millionth of a nanogram/L, that is 1 millionth of a thousandth part per million. These extraordinarily low concentrations do not represent a health hazard.

Summary by DGZ

Durakovic, Gerdes, and Zimmerman conclude their paper by stating that "our results provide the first objective analytical study of long-term contamination and possible association with adverse health effects in the current population of Port Hope."

These comments are misleading. It is not possible to identify long term contamination from a single urine specimen. The authors have merely demonstrated that their subjects have had uptake of uranium into their bodies. But everyone ingests uranium, and the results of DGZ demonstrate that the uptake of soluble uranium is less than the average in the United States. It is not possible to make any comment about poorly soluble uranium from these analyses. Most importantly, the authors **have no**t demonstrated "a possible association with adverse health effects". This was not a health study, but a measurement of biological excretion.

CONCLUSION

Durakovic, Gerdes, and Zimmerman have importantly demonstrated that **uranium excretion among residents of Port Hope is not elevated in comparison to populations in the United States and Europe.** There is no reason to expect any unusual pattern of health effects from uptake of uranium among residents of Port Hope.

Reference List

Galletti M, D'Annibale L, Pinto V, Cremisini C. 2003. Uranium daily intake and urinary excretion: a preliminary study in Italy. Health Phys 85:228-235.

Ting BG, Paschal DC, Jarrett JM, Pirkle JL, Jackson RJ, Sampson EJ, Miller DT, Caudill SP. 1999. Uranium and thorium in urine of United States residents: reference range concentrations. Environ Res 81:45-56