CHALLENGES OF ICRP 60 FOR URANIUM REFINING AND CONVERSION FACILITIES

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ABSTRACT

Cameco Corporation operates high-grade uranium mines in northern Saskatchewan and uranium refining and conversion facilities in Ontario. The dose limits for these and all other nuclear facilities in Canada are 50 mSv per year and 4 WLM per year, which are applied separately. However, the upcoming incorporation of the recommendations in ICRP 60 into the Canadian regulations will result in several important changes. In addition to a more restrictive dose limit, the new regulations will require that all radiation exposures be combined into a single index of exposure. Meeting the new lower dose limits of 50 mSv per year and 100 mSv per 5 years will not be a major problem at Cameco facilities. However, the incorporation of long-lived radioactive dust exposures into the dose calculation will be a major challenge. This will cause the most difficulty at the uranium refining and conversion facilities where much of the process involves handling a variety of uranium compounds in the form of a dry powder. At the uranium conversion facilities the control of exposure to airborne uranium is achieved through a combination of lung counting, urinalysis, and fixed area monitors. To progress from a system of exposure control to dose estimation to individual workers will require some major changes.

INTRODUCTION

Cameco Corporation operates uranium fuel conversion facilities in Ontario. The plant at Blind River receives uranium oxides from uranium mills and refines the material to nuclear grade UO_3. The UO_3 is then shipped to the Port Hope facility where it is converted to either UF_6 or UO_2 powder. These facilities currently process about 10,000 tonnes U per year.

While Cameco has extensive monitoring programs for airborne uranium at its Port Hope and Blind River facilities, doses from inhaled uranium are not assigned to individuals. The primary purpose of these programs is exposure control, not dosimetry. Continuous area samplers measure the airborne concentration of uranium; most stations are measured on a daily basis. A urinalysis and lung counting program is used to assess intakes of uranium. The primary purpose of the urinalysis program is protection of the kidney from the chemical hazards of uranium. The lung counter is a mobile unit using phoswhich detectors. All production and maintenance employees at the Port Hope and Blind River plants have a 30 minute lung count twice per year.

Exposure to all three types (F, M, and S) of uranium compounds is possible at Cameco's refining and conversion facilities. The facility with the highest potential for significant internal doses from inhaled uranium is the UO_2 Plant at Port Hope. This is because most of the airborne uranium is likely UO_2 and it is generally considered to be type S (class Y) material. While the potential for the highest doses exists at the UO_2 Plant, many of the challenges of implementing an internal dosimetry program are the same for all Cameco's refining and conversion facilities.

CANADIAN IMPLEMENTATION OF ICRP 60

The Atomic Energy Control Board (AECB) has recently published draft regulations that are intended to replace the current ones (AECB 1997). A key component of the draft regulations is the incorporation of most of the recommendations of the International Commission on Radiological Protection (ICRP) Publication 60 (ICRP 1990). This includes the effective dose limits of 100 mSv over a five-year period and 50 mSv in any single year.

Cameco does not anticipate any major problems meeting the new lower dose limits. However, incorporation of long-lived radioactive dust into the dose calculation will be a challenge. In particular, the AECB has indicated in a draft document on personal monitoring, that it will expect personal dosimetry to be used for any dose component that exceeds 5 mSv/y (AECB 1996). The draft document defines personal monitoring to be a direct measurement on the body, a measurement of material excreted or continuous personal air sampling. Non-personal monitoring is considered to be personal monitoring of selected individuals in a group of workers or area measurements combined with occupancy factors. The requirement for personal monitoring, if the dose exceeds 5 mSv/y, will have a major impact on the design of an internal dosimetry system.

The new ICRP lung model (ICRP 1994a) and the new biokinetic model for uranium (ICRP 1995) will also have a substantial impact on the details of any internal dosimetry system for uranium. A useful computer program called LUDEP, which implements the new ICRP lung model, is available from the British National Radiological Protection Bureau (Jarvis et al 1996). The program does not include the new biokinetic model for uranium, but still uses the ICRP 30 model (ICRP 1979).

IMPLICATIONS OF THE NEW ICRP LUNG MODEL

The Tables 1 and 2 list the annual limit on intake (ALI) and derived air concentration (DAC) for natural uranium compounds. Note that the ALI's according to LUDEP for Type F and M are more restrictive than those from ICRP 68 (1994b) because LUDEP has not yet incorporated the new biokinetic model for uranium.

Table 1 ICRP 68 ALI & DAC for U-Nat

Type	ALI -Bq		DAC - mg U/m^3	
	1 mm AMAD	5 mm AMAD	1 mm AMAD	5 mm AMAD
F	$3.849´10^4$	$3.280´10^4$	636.3	542.4
M	$7.022´10^3$	$1.082´10^4$	116.1	178.9
S	$2.534´10^3$	$3.203´10^3$	41.9	53.0

Table 2 LUDEP (v2.04) ALI & DAC for U-Nat

Type	ALI - Bq			DAC - mg U/m3		
	1 mm AMAD	5 mm AMAD	10 mm AMAD	1 mm AMAD	5 mm AMAD	10 mm AMAD
F	$1.018´10^4$	$8.676´10^3$	$1.039´10^4$	168.3	143.5	171.8
M	$5.871´10^3$	$8.729´10^3$	$1.619´10^4$	97.1	144.3	267.7
S	$2.512´10^3$	$3.188´10^3$	$5.223´10^3$	41.5	52.7	86.4

Subsequent analyses have been done for type M and S compounds with an activity median aerodynamic diameter (AMAD) of 1 mm, 5 mm and 10 mm. Exposures to uranium compounds outside this range of properties are not likely to have much potential to give a significant internal dose. To enable a consistent analysis of 10 mm dust to be done, the LUDEP ALI's have been used. Note that for Type M compounds the ALI should be about 20 percent higher.

Table 3 lists the implied effective dose from an observed 5 mg (126 Bq) U-Nat lung burden. Note that this is the detection limit for "fresh" U because the value from Th-234 peak may not be a reliable indicator of the uranium burden.

Table 3 Implied Effective Dose from Observed 5 mg U-Nat Lung Burden

Mode	Time since intake (month)	Type M 1 mm (mSv)	Type M 5 mm (mSv)	Type M 10 mm (mSv)
Acute	1.5	6.7	8.9	10.6
Acute	3.0	10.0	13.4	16.1
Acute	6.0	18.3	24.6	29.7
Chronic	(six mo. exposure)	8.7	11.4	13.7
Mode	Time since intake (month)	Type S 1 mm (mSv)	Type S 5 mm (mSv)	Type S 10 mm (mSv)
Acute	1.5	11.4	17.6	23.8
Acute	3.0	13.5	21.1	28.7
Acute	6.0	15.8	24.8	33.9
Chronic	(six mo. exposure)	12.6	19.6	26.6

The doses are quite large for this modest lung burden. These results show that lung counting would have problems doing accurate dosimetry for doses less than 10 mSv in a single year.

While the lung counter may have limited uses for dosimetry at doses less than 10 mSv in a single year, it can demonstrate compliance with the new dose limits. The lung burden from an intake that results in a 50 mSv dose is shown on Figures 1 and 2. The lung counts were assumed to take place at 6 months (June 30) and 12 months (December 31). The single intake scenario was assumed to take place on January 1; this is the worst case in terms of detecting the lung burden. It is also unrealistic, since it implies exposure to an airborne concentration of at least 7,500 mg U/m^3 (190 Bq/m^3) for an entire shift. The double intake scenario was modelled as two 25 mSv intakes, one occurring at the 3 months (March 31) and the other at 9 months (September 30). In all cases the lung burden would be easily detectable.

It is interesting to note that there is little difference in the lung burden between a chronic intake and a double intake. It is reasonable to assume that actual intakes are a combination chronic and acute events randomly scattered throughout the year. This suggests that at least for screening purposes, the chronic intake model is a reasonable one to use.

Figures 3 and 4 show the lung burden over a five-year period assuming a chronic intake equivalent to 20 mSv/y. The graphs show that over a five-year period, intakes at 20 mSv/y would easily be detected. However, the lung counter would not be able to detect a chronic 20 mSv/y intake for Type M compounds, if the AMAD were much greater than 10 mm.

It is apparent that the behaviour of Type M and S compounds is quite different. Type M compounds reach an equilibrium in the lung after about two years, while the lung burden of Type S compounds continues to increase. Tables 4 and 5 list the possible long-term missed dose for Type M and S compounds, respectively.

Table 4 Possible Long-Term Missed Dose for Type M Compounds
3 mg U-Nat detection limit assumed

AMAD	1 mm	5 mm	10 mm
Missed Dose	7.2 mSv/y	9.6 mSv/y	11.5 mSv/y
Implied airborne concentration	35 mg U/m^3 (0.88 Bq/m^3)	69 mg U/m^3 (1.7 Bq/m^3)	154 mg U/m^3 (3.9 Bq/m^3)

Table 5 Possible Long-Term Missed Dose for Type S Compounds
3 mg U-Nat detection limit assumed

AMAD	1 mm	5 mm	10 mm
Missed Dose at Year 5	3.2 mSv/y	5.0 mSv/y	6.8 mSv/y
Missed Dose at Year 10	2.5 mSv/y	3.9 mSv/y	5.3 mSv/y
Implied airborne concentration	6.6 mg U/m^3 (0.17 Bq/m^3)	13 mg U/m^3 (0.33 Bq/m^3)	29 mg U/m^3 (0.73 Bq/m^3)

The long-term missed dose for Type S compounds is not that high. For workers that never have an observed lung burden above the detection limit, there is a reasonable upper constraint on their total dose. This suggests that it may be possible to use the lung counter for dosimetry.

One limitation of the lung counter is it will not be able to distinguish between intakes of type M and S compounds. This is because the rate of clearance changes with time and there is considerable overlap between the two classes of material. For example, the rate of clearance of 1 mm type M compounds, 50 days after intake, is the same as 1 mm type S compounds 30 days after intake. In addition, the uncertainties in the data from the lung counter would make this an even more difficult task, at least for lung burdens less than 10 mg U-Nat. Finally, there is the practical problem of removing a worker from possible subsequent exposure for a sufficient time to allow a measurable quantity of uranium to clear the lung.

This is unfortunate because there is considerable difference in the calculated dose for a given lung burden, depending on the lung clearance type. The type of compound (M or S) would have to be assumed, based on knowledge of the worker's job. Special sampling campaigns would have to undertaken to characterise the lung clearance type and size of the dust in the workplace.

The situation is quite different for type F compounds, such as UO_2F_2. These compounds can be expected to clear within one or two days. Exposure to type F compounds is a possibility at all Cameco Fuel

Services Plants. Since the implied dose from any lung burden above the detection limit of type M or S compounds is quite large, a repeat lung count within a few days is warranted to determine if it is a type F compound. One would need to remove the worker from possible exposure or risk a false positive indication of type M or S compounds.

In the UO_2 Plant air sampling indicates that the annual dose from inhaled uranium may be in the range of 5 mSv to 20 mSv. This means that most of the long-term work force should have a measurable lung burden. However, most of the long-term employees (> 10 years) do not have a measurable lung burden. Each year a few workers have a lung burden ~ 5 mg U-Nat, but subsequent counts usually indicate a value less than the detection limit. The air sampling program indicates the potential for internal doses greater than 5 mSv/y, but the lung counter data show a pattern of infrequent intakes.

The lack of observed lung burdens among long-term employees, despite the relatively high airborne concentrations, suggests that the respirator program is effectively protecting the workers. Both the Blind River and Port Hope facilities make extensive use of respirators. The respirator program follows the requirements of CAN/CSA-Z94.4-93 *Selection, Use, and Care of Respirators*. (CSA 1993). While this is good news from a radiation protection point of view, it creates a problem for the internal dosimetry program. Specifically how does one take credit for respirator use? Since it is likely that at least part of the internal dosimetry program will be based on air monitoring, taking credit for respirator protection is important to keep the calculated doses realistic.

To formally take credit for respirator use it would be necessary for their use to be better defined. Some areas and/or jobs would have to be designated as mandatory respirator use. This may require physically isolating some areas, such as the UO_2 blending area. Another way to help make the use of respirators better defined would be to use continuous airborne monitors with alarms. These devices are used at some other uranium processing facilities around the world, but not at Cameco facilities. We are currently assessing their possible use at Cameco facilities.

POSSIBLE INTERNAL DOSIMETRY PROGRAMS

The lung counter is considered to be personal monitoring and for exposure to type S compounds with an AMAD ~ 5 mm the long-term missed dose is below 5 mSv/y. Since most long-term employees have a lung burden below the detection limit, their internal dose has likely averaged less than 5 mSv/y. One could use this information to infer that the dose for the current year is consistent with the long-term missed dose. It would be necessary to show that other indicators, such as airborne monitoring and urinalysis, have also remained consistent.

While the lung counter cannot be ruled out for dosimetry purposes, there are several problems with this approach. First, data on the size distribution is needed to determine if this is feasible. Port Hope and Blind River have started to collect the required size data. Another problem is that for anyone with a lung burden, it can become quite complicated to perform a dose assessment. The reason for this is a significant portion of the lung burden from a type S compound would remain in the lung for more than one year. One would need to model the future lung burden and subtract this result from any future observed results.

It should be pointed out that even if an airborne monitoring system is adopted, it will be difficult to ignore the dose implications of a confirmed type M or S lung burden. For example, a lung burden of 8 ±1mg (assuming a chronic intake of 5 mm AMAD type S material) implies a dose of 32±4 mSv. Lung burdens at this level are occasionally observed and the air monitoring data suggest that doses at this level are possible. In such a case one would likely be forced to conclude that the respirator program for that particular individual failed.

If it is not possible to use the lung counter for dosimetry, some form of air monitoring will be required. The preferred approach would be to collect a sufficient number of samples for every individual to quantify each person's exposure at the required level of accuracy. This would probably require at least 20 to 30 full shift samples per worker per year. Obviously there are significant costs associated with this type of program.

An important component of the internal dosimetry system that still needs to be investigated is the urinalysis program. However, this work cannot be done until the new urinary excretion and kidney retention functions for the new uranium biokinetic model are available.

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Figure 1: Lung Burden from 50 mSv Intake: Type M Uranium Compounds

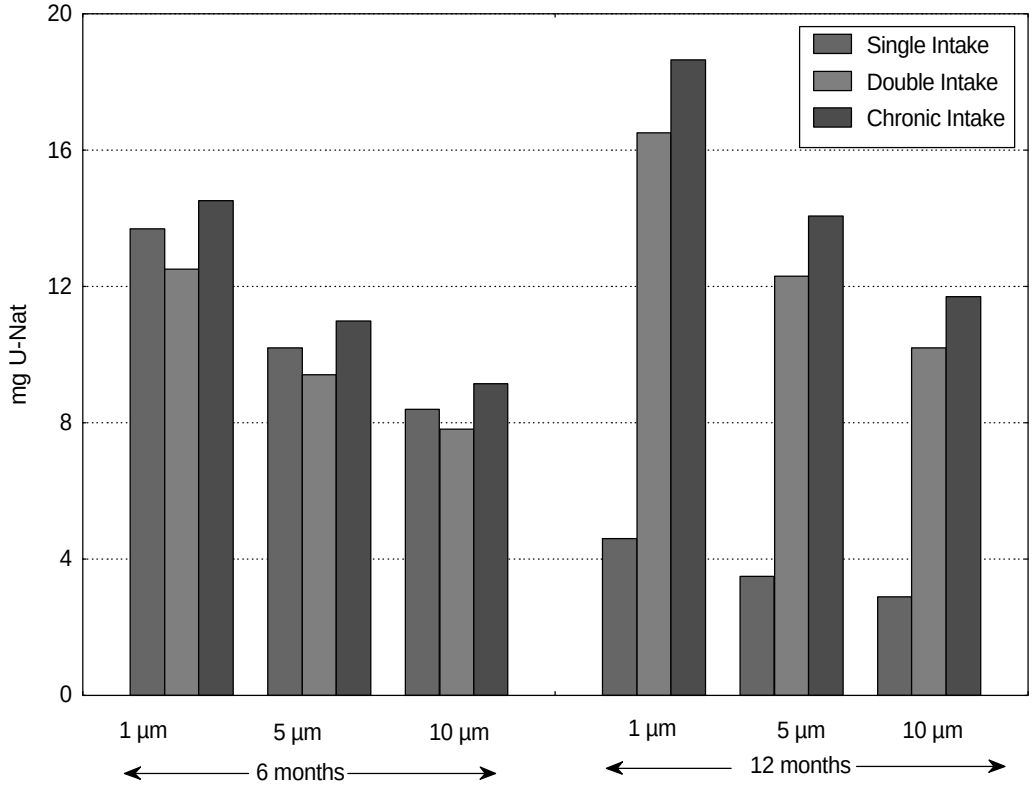

Figure 2: Lung Burden from 50 mSv Intake: Type S Uranium Compounds

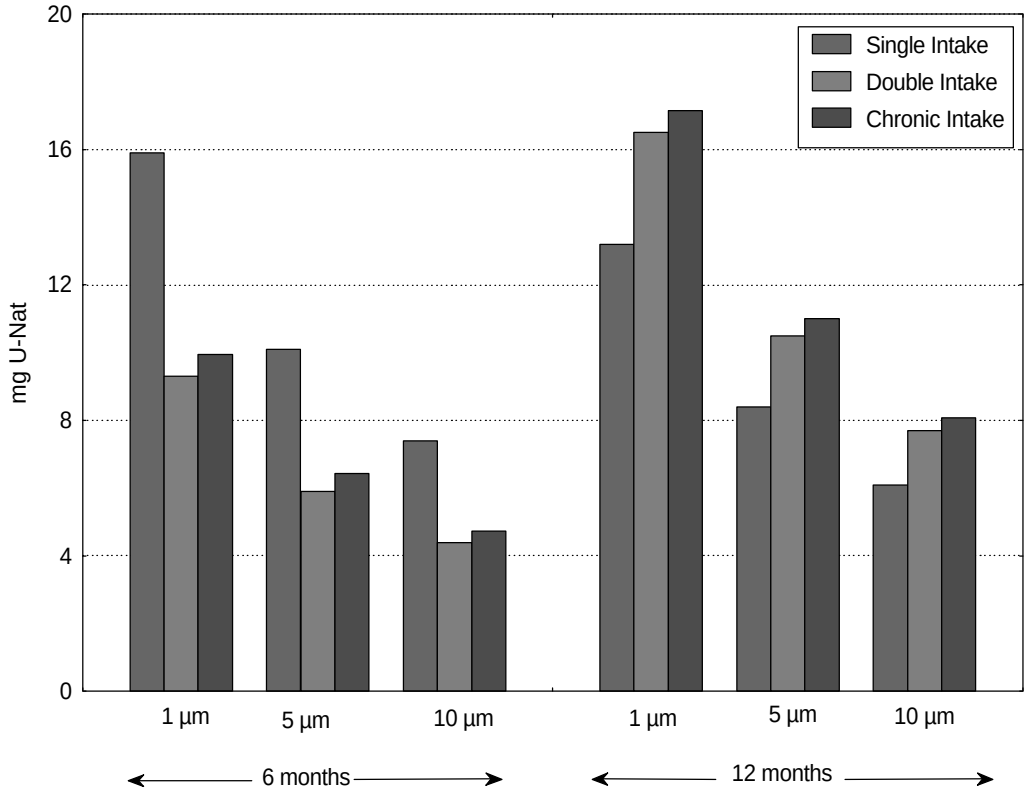

Figure 3: Lung Burden from Chronic 20 mSv/y Intake for 5 Years

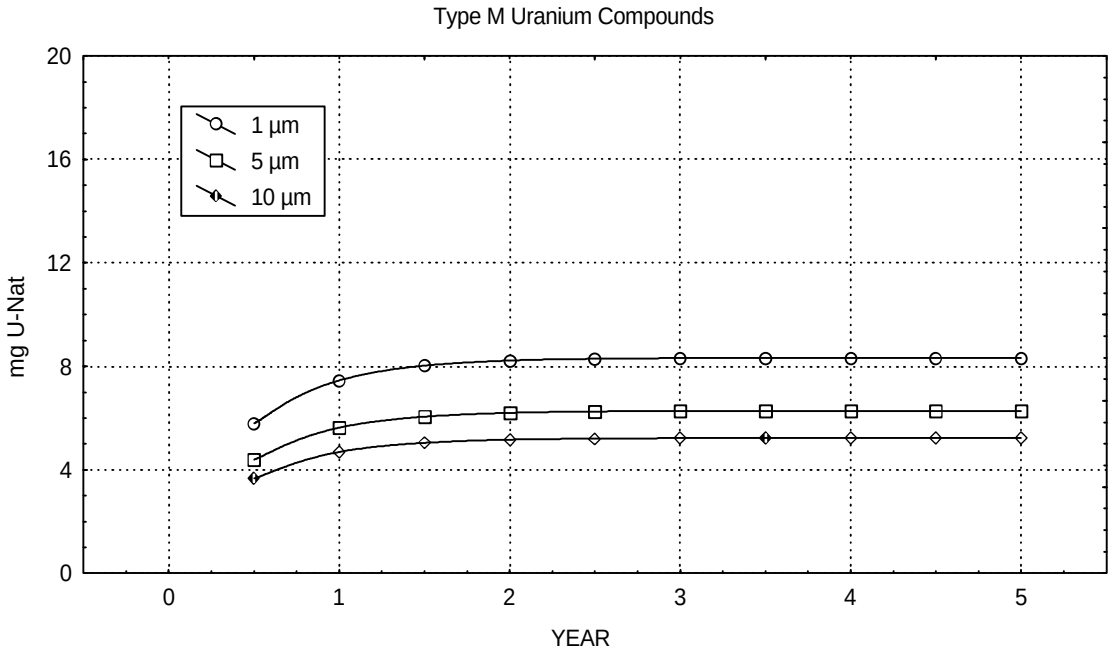

Figure 4: Lung Burden from Chronic 20 mSv/y Intake for 5 Years