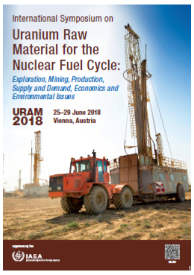

Contribution ID: **213** Type: **ORAL**

Action Levels for Airborne Natural Uranium in the Workplace: Chemical and Radiological Assessments

Wednesday, 27 June 2018 14:40 (20 minutes)

INTRODUCTION

Intakes of natural uranium (U) present two hazards to workers, namely chemical and radiological. The consequence of too much intake can be chemically induced damage for which kidney is the primary target tissue, or radiogenic cancer for which lung appears to be the primary target tissue. The chemical damage to the kidneys depends on the concentration of U in the kidneys. Nephrotoxicity is thought to be the greater risk for inhalation of relatively soluble forms of natural U due to a high fractional absorption of U to blood and uptake and retention by the kidneys. The radiological risk of lung cancer depends on the radiation dose to the lungs. Lung cancer is thought to be the greater risk for inhalation of relatively insoluble forms of natural U due to extended retention of the inhaled material in the lungs. Neither the concentration of U in the kidneys nor the cumulative irradiation of the lungs can be directly measured, but both quantities can be assessed using biokinetic models.

DESCRIPTION

In the workplace the primary and most significant intake of U typically is from inhalation. Continuous measurements of the concentration of U in air at work locations can be used together with the most recent, internationally accepted models to estimate the concentration of U in the kidneys and the dose to the lungs from inhalation.

We reviewed the scientific literature to evaluate the relation of the concentration of U in the kidneys to various levels of levels of damage to the kidneys and to propose a limiting kidney concentration (called primary chemical guidance in the following) for U as a chemical hazard [1-9]. We used primary guidance of the International Commission on Radiological Protection (ICRP) as a limit on intake of U as a radiological hazard [10]. These primary guidance levels for U as chemical and radiological hazards were used, together with best available biokinetic and dosimetric models [11-13], to derive "action levels"for U exposure in the workplace as represented by the concentration of airborne U.

Two levels of primary guidance are proposed for the purposes of avoiding chemical effects of U and limiting its potential radiological effects to ICRP's recommended levels defined in terms of effective dose. The lower level of primary guidance is used as the basis for determination of an investigation level (IL) of airborne U. An IL indicates the need to confirm the validity of moderately elevated measurements and adequacy of confinement controls and determine whether work limitations are needed. The higher level of primary guidance is used as the basis for determining an immediate action level (IAL). An IAL indicates that safety measures should be put into place immediately, including removal of workers from further exposure until conditions are acceptable. An action level is reached if model predictions based on current air monitoring data, together with best available information on the form of U in air, that either the limiting chemical guidance or the limiting radiological guidance could eventually be exceeded if the air concentration is not reduced. The lower level of primary guidance is 0.3 µg U / g kidney for avoidance of chemical effects and 2.0 mSv y-1 for limitation of radiological effects. The higher level of primary guidance is 1.0 µg U / g kidney for avoidance of chemical effects and 5.0 mSv y-1 for limitation of radiological effects.

For each of several different levels of solubility of airborne U, ranging from highly soluble to highly insoluble forms, models were used to predict the lowest concentration of U in air that would eventually yield the limiting

U concentration in the kidneys of a chronically exposed worker. For each solubility level, a similar calculation was performed to predict the lowest concentration of airborne U that would eventually yield the limiting annual effective dose to a chronically exposed worker. The biokinetic models (and dosimetric models in the case of radiological considerations) used in these calculations were those recommended in ICRP Publication 137 [13].

For intake of a given concentration of U in air, both the effective dose and the peak kidney concentration depend on the solubility of the U compound, so that the IL and IAL both vary with the solubility of airborne U. ILs and IALs were derived for each of the Absorption Types (solubility classes) for U addressed in ICRP Publication 137 [13]. That report defines five Absorption Types for U, representing a range of dissolution levels. In order of decreasing solubility the five levels are as follows: Type F (fast dissolution, e.g., UF6), Type F/M (somewhat slower dissolution than Type F, e.g., UO2(NO3)2), Type M (moderately soluble, e.g., UF4), Type M/S (somewhat slower dissolution than Type M, e.g., U3O8), and Type S (very slow dissolution; no examples are given in Publication 137 but presumably Type S would include high-fired oxides).

DISCUSSION AND CONCLUSION

To derive radiologically based action levels, we assumed that U contains 0.0057% 234U, 0.72% 235U, and 99.27% 238U by mass. Despite its small percentage of mass, 234U contributes significantly to the total dose, because its specific activity is on the order of 10,000 times greater than that of each of the other two nuclides. Effective dose coefficients for the assumed mixture of natural U isotopes were based on effective dose coefficients given in ICRP Publication 137 [13] for the individual isotopes. It was assumed that 234U, 235U, and 238U represent 50.45% 2.2%, and 47.35%, respectively, of inhaled U, based on their relative masses and specific activities of 2.32 ⊠ 108, 8.01 ⊠ 104, and 1.25 ⊠ 104, respectively [5].

The solubility of airborne U is a key variable regarding both the chemical and radiological risk to an exposed worker. If inhaled U is highly soluble, it is removed quickly from the lungs with a sizable portion being absorbed to blood and the remainder entering the alimentary tract. The absorbed U yields some radiation dose to systemic tissues, but most of the absorbed activity is removed in urine over a period of days. The main hazard from the absorbed U is thought to be its relatively high accumulation in the kidneys and its subsequent chemical effects on kidney tissue. If inhaled U is highly insoluble, much of it will be retained in the deep lungs for an extended period, possibly decades, and little will reach the systemic circulation. In this case, the main hazard from the inhaled U is expected to be its prolonged alpha irradiation of lung tissue, potentially leading to lung cancer. Thus, chemical toxicity to the kidneys is presumably the dominant risk from relatively soluble U in air, and radiological toxicity is presumably the dominant risk from relatively insoluble U in air. The chemical risk decreases and the radiological risk increases with decreasing solubility of airborne U. In terms of the Absorption Types defined in ICRP Publication 137, the chemical risk decreases in the order Type F > Type F/M > Type M > Type M/S > Type S, and the radiological risk decreases in the order Type S > Type M/S > Type M > Type F/M > Type F.

The radiological risk depends on the isotopic composition of U in air, as 234U has a much higher specific activity than 235U or 238U. Calculations of chemical toxicity are simpler than those for radiological risk, because the chemical processes depend on the total mass of U in the kidneys and are independent of the isotopic distribution. Thus, for evaluation of chemical risk from a given concentration of U in air, it suffices to use a biokinetic model to predict the time-dependent mass of U in the kidneys. The biokinetic models applied are taken from ICRP Publication 137 and are the same as those used to predict the distribution of inhaled radioactivity.

For a worker to be protected from both the chemical and radiological hazards of a given form of U, the lower of the limiting values based on chemical and radiological considerations should be applied.

Chemically and radiologically based ILs and IALS were derived using the biokinetic models, dosimetric models, and Absorption Types for U defined in ICRP Publication 137 [13]. A particle size of 5 um AMAD was assumed. This is the ICRP's default particle size for inhalation of radionuclides in the workplace.

The derived radiological IL in µg m -3 for F is 1350; for F/M is 824; for M is 244; for M/S is 61.6; for S is 25.4. The derived chemical IL in µg m -3 for F is 30; for F/M is 56; for M is 81; for M/S is 167; for S is 253. For example, for Type M the chemically based IL is 81 µg m -3 and the radiologically based IL is 244 µg m -3, so the chemically based value of 81 µg m -3 is used as the IL.

The derived radiological IAL in µg m -3 for F is 3376; for F/M is 2060; for M is 610; for M/S is 154; for S is 63.5. The derived chemical IAL in µg m -3 for F is 101; for F/M is 188; for M is 272; for M/S is 563; for S is 845. The more restrictive is shown in boldface. For example, for Type M/S the chemically based IAL is 563 µg m -3 and the radiologically based IAL is 154 µg m -3, so the radiologically based value of 154 µg m -3 is used as the IAL.

If the solubility is unknown, the most limiting action level should be used. Based on the above values, the most limiting IAL value is the chemically based limit of 30 µg m -3, assuming a particle size of 5 µm AMAD. Ideally the limiting air concentration would be based on site-specific information on the particle size as well as the solubility of airborne U.

There are several work environments where U may be inhaled in relatively high quantities. These include underground mining, surface mining, in situ leaching, phosphate processing, and heavy metal processing. Each of these has different characteristics of the solubility of the aerosols and the particle size. These characteristics must be identified and used to assess the applicability of models for the protection of the workers. In addition to U, there are other radionuclides that must be assessed and controlled. Radon and its progeny are particularly important for control in the workplace.

REFERENCES
[1] Dorrian, M. D.; Bailey, M. R. (1995). "Particle size distributions of radioactive aerosols measured in workplaces."Radiat. Prot. Dosim. 60:119–113.
[2] Foulkes, E. C. (1990). "The concept of critical levels of toxic heavy metals in target tissues."Crit. Rev. Toxicol. 20:327–339.
[3] Guilmette, R. A.; Parkhurst, M. A.; Miller, G.; Hahn, F. F.; Roszell, L. E.; Daxon, E. G.; Little, T. T.; Whicker, J. J.; Cheng, Y. S.; Traub, R. J.; Lodde, G. M.; Szrom, F.; Bihl, D. E.; Creek, K.L.; McKee, C. B. (Project Administrator) (2004). "Human health risk assessment of Capstone depleted U aerosols. Attachment 3 of Depleted U Aerosol Doses and Risk: Summary of U.S. Assessments"(Richland WA USA): Battelle Press, October 2004.
[4] Leggett, R. W. (1989). "The behavior and chemical toxicity of U in the kidney: A reassessment."Health Phys. 57:365–383.
[5] Leggett, R. W.; Eckerman, K. F.; McGinn, C. W.; Meck, R. A. (2012). Controlling intake of U in the workplace: Applications of biokinetic modeling and occupational monitoring data. ORNL/TM-2012/14. January 2012. Oak Ridge National Laboratory, Oak Ridge, TN. https://info.ornl.gov/sites/publications/Files/Pub34411.pdf
[6] McDiarmid, M. A.; Engelhardt, S. M.; Dorsey, C. D.; Oliver, M.; Gucer, P.; Wilson, P. D.; Kane, R.; Cernich, A.; Kaup, B.; Anderson, L.; Hoover, D.; Brown, L.; Albertini, R.; Gudi, R.; Squibb, K. S. (2009). "Surveillance results of depleted U-exposed Gulf War I veterans: Sixteen years of follow-up."J. Toxicol. Environ. Health A. 72:14-29.
[7] Morrow, P. E.; Gelein, R. M.; Beiter, H. D.; Scott, J. B.; Picano, J. J.; Yuile, C. L. (1982). "Inhalation and intravenous studies of UF6/UO2F2 in dogs."Health Phys. 43:859–873.
[8] Keith L S, Faroon, O M and Fowler, B A 2015 Chapter 59 –U In: Handbook on the Toxicology of Metals 4th edition, vol 2, G Nordberg, ed London: Academic Press pp 1307-45
[9] Stopps G J and Todd M 1982 The Chemical Toxicity of U with Special Reference to Effects on the Kidney and the Use of Urine for Biological Monitoring INFO 0074 Atomic Energy Control Board of Canada, Box 1046, Ottawa, K1P5S9
[10] ICRP (2008). International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103. Oxford: Pergamon Press.
[11] ICRP (2015). International Commission on Radiological Protection. Occupational Intakes of Radionuclides: Part 1. ICRP Publication 130. London: Sage Publications.
[12] ICRP (2016). International Commission on Radiological Protection. The ICRP computational framework for internal dose assessment for reference adults: Specific absorbed fractions. ICRP Publication 133. London: Sage Publications.
[13] ICRP (2017). International Commission on Radiological Protection. Occupational Intakes of Radionuclides.Part 3. ICRP Publication 137. London: Sage Publications.

Country or International Organization

USA

Primary author: Dr MECK, Robert (Science and Technology Systems)

Co-author: Dr LEGGETT, Richard (Oak Ridge National Laboratory)

Presenter: Dr MECK, Robert (Science and Technology Systems)

Session Classification: Health, Safety, Environment and Social Responsibility

Track Classification: Track 10. Health, safety, environment and social responsibility