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U-BEARING PARTICLES IN MINERS' AND MILLERS' LUNGS*

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ABSTRACT

The size distribution of uranium-bearing particles in air particulates in occupational areas of active uranium mines and mills is largely uninvestigated. Investigation of the size of residual uranium-bearing particles in uranium miners' and millers' lungs is warranted because significant inhalation of uranium can occur in certain occupational areas. Average uranium concentrations of about 0.3 ppm U in uranium miners' and millers' lungs have been reported. Local uranium concentrations in uranium-bearing particles inhaled and regionally deposited in the lungs of uranium miners and millers are orders of magnitude larger than the average uranium concentrations reported. The feasibility of using microPIXE (particle induced x-ray emission) techniques to search for such uranium-bearing particles embedded in lung tissues has been demonstrated. Proton microbeams 20 μm in diameter, scanning in 5 μm steps, were used to irradiate sections of lung tissues 10 to 40 μm thick. The paper will briefly describe the method, and present and discuss the results obtained in an extensive search for uranium-bearing particles embedded in lung tissues, collected at autopsy, of former uranium miners and millers.

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The size distribution of uranium-bearing particles in air particulates in occupational areas of active uranium mines and mills is uninvestigated, though interesting data on the uranium content of air particulates near a uranium mine and in a uranium mill have been published (1,2). Investigation of the size of residual uranium-bearing particles in uranium miners' and millers' lungs is warranted, because significant inhalation of uranium can occur in certain occupational areas. Table 1 summarizes typical uranium concentrations in the precipitation, drying and packaging areas of Canadian uranium mills, based on data from Pomroy et al. (3).

Table 1. Typical uranium concentrations in Canadian uranium mills for the year 1980. Data taken from Pomroy et al. (3)

Area	Concentration $\mu g\ U/m^3$
Precipitation	9 - 93
Drying	45 - 117
Packaging	60 - 301

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According to Table 1, levels of uranium concentrations in the precipitation and drying areas, where respiratory protection is not mandatory, range from 9 to 117 μg U/m^3. These levels are below the $(MPC)_a$ for uranium in occupational areas, which are 210 and 180 μg U/m^3 for insoluble and soluble uranium compounds respectively (4). However, the derived air concentrations (DAC) for uranium inhalation, as recommended by ICRP 30, are: 20 Bq $^{238}U/m^3$ (i.e., 540 pCi $^{238}U/m^3$ or ≈ 1600 μg U/m^3) for class D compounds such as UF_6, UO_2F_2 and $UO_2(NO_3)_2$; 10 Bq $^{238}U/m^3$ (i.e., 270 pCi $^{238}U/m^3$ or ≈ 800 μg U/m^3) for class W compounds such as UO_3, UF_4 and UC_{14}; and 0.7 Bq $^{238}U/m^3$ (i.e., 19 pCi $^{238}U/m^3$ or ≈ 56 μg U/m^3) for class Y compounds such as UO_2 and U_3O_8 (5). Thus, some concentrations of uranium in air listed in Table 1 are higher than the class Y DAC recommended by ICRP 30 for U_3O_8. Borak et al. calculated a series of DACs for uranium in ore dust based on different dose limitation systems (6). These DACs are as low as 0.6 μg U-nat/m^3 (for 0.5 μm activity median aerodynamic diameter - AMAD) up to 19 and 23 μg U-nat/m^3 (for 5.0 μm AMAD) based on weighted dose equivalent commitment with a weighting factor of 0.12 for relative risk of cancer induction for long irradiation in comparison with the whole body and final generic environmental impact statement on uranium milling, assuming an annual dose equivalent limit of 15 rem/yr, respectively (6,7). Most recently, however, McGuire reviewed the rationale behind the currently adopted limit on intake by inhalation of airborne uranium ore dust from mines and mills, pointing out based on reports published in the literature that uranium ore dusts in mills are associated with particles of about 10 μm (8). McGuire went further to introduce a DAC for uranium ore dust, assuming equilibrium of ^{238}U with a mixture of its long-lived alpha emitter daughters present in dust, equal to 0.6×10^{-10} μCi/ml (considered to be equivalent to 45 μg U/m^3) (8). The present NRC standard is 1×10^{-10} μCi/ml (i.e., 75 μg U/m^3 or 3.7 Bq/m^3). The different DACs presented above allow one to observe that uranium concentrations in occupational areas might or might not exceed a specific DAC, depending on parameters like radioactive equilibrium in the ore dust and particle size distribution. In addition, studies reported by Chan and Lippmann suggested the possibility of a significant tracheobronchial deposition of particles around 10 μm MMAD (mass median aerodynamic diameter) (9). Although the MMAD and the AMAD were considered equivalent by the ICRP (10), Kotrappa et al. indicated that this is the case only when there is a well defined proportionality between mass and activity of the particles (11).

Furthermore, Singh et al. reported an average concentration in uranium miners' lungs of 89 pCi/kg wet weight (≈ 0.3 ppm U) in 13 autopsy samples with a range from 6.1 to 311 pCi ^{238}U/kg wet weight (12). These authors suspect that the uranium concentrations in miners' lungs might be associated with large inhaled particles which do not clear the lungs as rapidly as submicron particles. Taking into account the large mass of the lungs in comparison with the small mass and diameter of uranium-bearing particles regionally deposited in the lungs, the local uranium concentrations in these particles are orders of magnitude higher than the average uranium concentration (≈ 0.3 ppm U) reported by Singh et al. (12) in uranium miners' lungs. Paschoa et al. demonstrated the feasibility of using microPIXE (particle induced x-ray emission) techniques to search for uranium-bearing particles in lung tissues, when the local uranium concentrations are higher than about 5 ppm U (13). Sections of lung tissues 10 to 40 μm thick were bombarded with a 20 μm proton beam, and x-ray spectra were obtained. The integrated number of counts under the L_α x-ray peak of U at 13.6 keV was used to quantitate the local mass of U being irradiated locally with the microbeam of protons in sections of lung tissues. Proton beam scanning with 5 μm steps at perpendicular directions were used to cover parts of lung tissues suspected to house particles. The paper will brifly describe the method, and present and discuss results obtained in an extensive search for uranium-bearing particles embedded in lung tissues, collected at autopsy, of former uranium miners and millers.

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