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Working Paper

FECAL SAMPLING FOR URANIUM EXPOSURE

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Introduction

Urine sampling has traditionally been used in the nuclear industry as an index of exposure to internal radionuclides and to aid in estimating body or organ content. More recently, in vivo counting of photons leaving the body burden of radioactivity has found favor because of its apparently unequivocal data and its ability to rapidly assess body burdens. If both of these methods are well established, why should anyone consider a third, by no means well established, bioassay technique?

For all radionuclides, fecal sampling is invaluable for early assessment of inhalation exposures where the amount inhaled is too small for in vivo detection or where photons of suitable energies aren't emitted by the particular radionuclides. For most radionuclides, information on the urine to fecal excretion ratio is necessary for complete interpretation of urine data. Finally, for some radionuclides, that is for some physio-chemical forms of some radionuclides, fecal sampling may permit the estimation of lung burdens.

This paper reviews fecal sampling as a general technique and then focuses on its application to exposures to uranium dust. As far as is possible, the approach here is practical and applied. The format is not in the style of a standard, but serves as a basis for discussion.

The Metabolic Mechanisms of Fecal Excretion

Radionuclides leave the body by at least four different routes.[4] The sweat is not an important route of excretion, at least for practical bioassay. Exhaled breath is analyzed in special cases for radon, thoron or $^{14}CO_2$. While the urine is the traditional choice for assay of internal burdens, analysis of the radioactivity in the feces can also yield useful information, but correct interpretation of fecal analysis data must take into account how the radioactivity got into the fecal material.

Eakins and Morgan[8] point out that material excreted in the feces may be endogenous or exogenous in origin. That is, radioactivity which has been absorbed into the body's circulating blood system and then is eliminated in the feces is endogenous in origin, Zn, Ba, Ce, Po, Th, Ra are examples of elements which are eliminated predominately in the feces,[5] even from internal organ deposition. Such elements enter the gastrointestinal tract either directly through the epithelium, or in bilary excretions in the liver. Uranium is not one of these elements.

Exogenous radioactivity in the feces has never actually been inside the body. Langham used to represent the body as an elongated donut where the G.I. tract was the hole in the middle. The lung could then be thought of as a pouch in hole wall. Consequently, inhaled dust which doesn't transport readily across lung or G.I. tract membranes will if it is cleared, appear in the feces. Of course, any material taken into the mouth which doesn't transport across the G.I. membranes also is eliminated in the feces.

The kinetics of clearance of inhaled particles was discussed extensively by the ICRP task group on lung dynamics.[1] Their principal departure from the earlier, ultra-simplified, ICRP clearance model[3] was to acknowledge that clearance depends very strongly on the physio-chemical characteristics of the inhaled particles. They grouped the elements and their compounds into 3 compound classes, D, W and Y, representing increasing non-transportability. The oxides, hydroxides and carbides or uranium are cleared slowly from the lung and are thus classified as Y compounds. All other compounds of uranium should be considered class W, although some authors claim that UF_6 is cleared very rapidly from the lung. The constants used in the 1966 clearance model have been revised recently.[2]

Clearance from the N-P region to the G.I. tract is now rated with a half time of 0.4 day (instead of 4 minutes), from the T-B region to the G.I. tract with a half time of 0.2 day (versus 10 min) and 50 days for class W and 500 days for class Y (as contrasted to 90 days and 360 days previously) from the pulmonary region.

To summarize, radioactivity which appears in the feces originates either from internal burdens or from lung clearance. Lung clearance is essentially bi-phasal; there is a rapidly cleared large fraction from any given inhalation which appears in the feces in the first few days after the inhalation. The later lung clearance is slower and, at least in the view of the ICRP task group, exponentially decreases with time. This late clearance from the lung can be complicated by endogenous fecal excretion if there is also an internal burden of an isotope which is excreted significantly in the feces. This shouldn't be true for uranium.

Interpretation of Fecal Sampling Data

The most important use of fecal sampling data is for estimating the magnitude of single inhalations from accidental exposures. Depending on the regions of deposition and hence on the particle size distribution of the inhaled particles, between 55% to 99% of class Y compound particles are cleared to the G.I. tract within the first few days. So, if all fecal excretions are analyzed over the first several days one knows within a factor of 2 how much radioactivity was inhaled. If one also knows the AMAD for the inhaled particles, one can know the inhalation more precisely and can also estimate what the lung retention is. This capability is especially valuable when a whole body counter is not available, when the radioactivity does not produce suitable photon radiation or when the burden is too small for in vivo measurements. The first good estimate of potential inhalation from an accident can be made by a rapid analysis of the first one or two fecal excretions after an exposure incident. This can often be done by gamma scanning the sample in its container before it is shipped to the bioassay laboratory. One can thus "size" an exposure earlier by this method than even in vivo counting where external body contamination and low sensitivity can produce confusing results in the first day or two.

Not realizing that many endogenous elements are excreted significantly in the feces has been a source of confusion in interpreting urine excretion data. Appendix C of ICRP Report 10A lists the fractions of total excretion by urine and feces for uptakes of various elements. Uranium is the one element listed with zero fecal excretion from internal depositions. This is not consistent with my experience,[9] but, if true, means there is no endogenous fecal excretion of uranium to complicate interpretation of late fecal clearance from the lung.

To estimate lung burdens of uranium from late fecal clearance data, one would collect several samples over a time sufficiently long to generate the excretion function. Using the operations prescribed in ICRP Report 10, the excretion function is integrated over the appropriate limits to arrive at the lung retention at any time.

There may be difficulties with this optimistic approach. For one thing it's been my observation that late fecal clearance is not always exponential. This means that the clearance mechanism is either not simple or not from a single compartment. Further, Mercer has suggested that there is no late clearance from the lungs via the phagocytosis - ciliary escalator route as suggested by the task group on lung dynamics. He gives convincing evidence that late clearance is primarily due to dissolution of the particles. If he's right, then late fecal clearance is only endogenous and couldn't be used to estimate lung burdens. Definite biological experiments need to be done to confirm this theory.

Mechanics of Fecal Sampling

Fecal sampling is generally considered by many health physicists to be objectionable to employees. I and many others have found that employees are cooperative once the proper techniques are established.

The correct kind of containers is that which prevents the spread of odor. Plastic refrigerator cartons are best. Lids should be taped on by the employee to seal in smell. Preservative such as formaldehyde can be added without opening the container by injecting the carton with a large hypodermic syringe. The resulting hole can be sealed with plastic adhesive. Paper or cardboard containers should be avoided. They transmit odor readily.

Written instructions should accompany the sampling kit. First timers are usually not quite sure how they are going to manage the collection of the sample. Everything the employee will need, carton, tape, carton carrier, etc., should be included in the kit supplied. Provision for marking the ~~tube~~ time of elimination must be included.

To prevent low level contamination of samples, they must be collected in clean areas, preferably at home. The written instructions should include procedures on handling the container, washing hands and return of the container to preclude accidental contamination.

It is important to know the wet weight of the fecal sample. Therefore, containers should be tare weighed (with tape) before issue. If dry ashed by the analytical laboratory the dry ash weight of the sample is useful and should be requested.

The Role of Fecal Sampling in a Uranium Plant Health Physics Program

There is not sufficient reason for a routine fecal sampling program in a uranium plant. Routine bioassay is designed to identify individuals who have accumulated a burden which is worth investigation. Fecal excretion of endogenous burdens is certainly low if not zero. Thus fecal sampling is completely inappropriate for monitoring this entire class of deposition. A case can be made for fecal sampling to monitor lung burdens of enriched uranium oxides which may fail to be transported in sufficient quantities for urine monitoring. But in vivo monitoring is adequate for this purpose. And as pointed out above, it is not yet clear that late fecal excretion is directly related to lung burden. Consequently, routine programs should be based on urine sampling or, better, in vivo counting.

The proper role of fecal sampling is early assessment of accidental exposures and special programs to gain specific information. For example, if one wishes to determine the exposure of a group of employees engaged in UO_2 powder handling, early fecal clearance can provide a more accurate index of exposure than stationary air sampling. It is also feasible to conduct plant wide fecal sampling occassionally as a screening technique to find sources of exposure of which you may not be aware.

References

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