UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

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MEMORANDUM FOR: Robert B. Minogue, Director
Office of Standards Development

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER # 73 - IN VIVO COUNTING AT SELECTED URANIUM MILLS

This memorandum transmits the results[1] of completed research on the measurement of natural uranium deposited in the lung and radium deposited in the skeleton of workers at nine uranium mills. This work was performed by Helgeson Nuclear Services, Inc., under the direction of the Environmental Effects Research Branch of RES, in response to a request from your office.

The measurements of uranium lung burden and radium skeletal burden were performed at the mill sites in one of Helgeson Nuclear Services' mobile scientific laboratories. Two different whole body counters were used for the measurements. For lung counting, a pair of 5-inch diameter phoswich detectors were held against the subject's chest by an elastic band which allows them to move up and down as the subject breathes in order to maintain constant lung-to-detector geometry. The radium is measured by an 8-inch diameter by 4-inch thick thallium activated sodium iodide detector which scans along the subject's body.

Calibration of the in vivo counting systems was performed by distributing radioactive sources with known activities inside standard phantoms and then performing the measurements exactly as is done for human subjects. Because of the absorption of low energy photons, it was necessary to develop curves which show the calibration factor for uranium as a function of chest thickness. Calibration factors for radium were found to be quite insensitive to the positioning of the source. Defining the minimum detectable activity (MDA) as three times the standard deviation of the background counting rate divided by the calibration factor, the limit of sensitivity for two phoswich detectors is 35 to 50 micrograms of uranium-235, which corresponds to 17 to 28 percent of the maximum permissible lung burden. The limit of sensitivity for the thallium activated sodium iodide detector is 6 to 10 nanocuries of radium-226 or 6 to 10 percent of the maximum permissible body burden.

[1] In Vivo Counting at Selected Uranium Mills, NUREG/CR-0841

Because of the low levels of activity deposited in the workers' bodies and the very high backgrounds due to the mill environment, data reduction involved complicated subtraction and curve fitting techniques. Corrections were made for cosmic ray interferences which are significant at the high altitudes where the mills are located.

Table 1 shows a representative sample of the different occupations involved and contains uranium and radium-226 results for each individual counted (identified by number and job title only) for one of the companies studied. Table 2 presents uranium results by company in terms of the arithmetic mean and standard deviation as well as the geometric median and its standard deviation. Table 3 presents radium-226 results in the same format. Table 4 presents the uranium results as a function of job title. The range of all uranium results is from a low of 0.8 mg to a high of 15.1 mg, while the mean of the population of 131 individuals is 5.6 $\pm$ 3.5 mg at one standard deviation. The range of all radium results is from a low of one to a high of 43nCi, while the mean of the population of 127 individuals is 9.1 $\pm$ 8.9 nCi at one standard deviation.

We recommend that the results presented in NUREG/CR-0841 be used by your staff in determining the value of taking in vivo measurements at mill sites. The RES technical contact for this work is Dr. Judith D. Foulke, Environmental Effects Research Branch (427-4358).

Saul Levine

Saul Levine, Director
Office of Nuclear Regulatory Research

Enclosure: NUREG/CR-0841

Subject	Job Title	Date & Time	Uranium mg	Radium 226 nCi
1	Acid Operator	4/25/77 @ 1609 4/25/77 @ 1526	7.0 ± 1.6	-ND- (1)
2	Metallurgist	4/25/77 @ 1438 4/25/77 @ 1356	11.5 ± 2.2	1 ± 10
3	Maintenance	4/25/77 @ 0745 4/25/77 @ 0703	4.1 ± 1.0	0 ± 7
4	Maintenance	4/25/77 @ 1140 4/25/77 @ 1156	10.7 ± 1.8	-ND-
5	Helper	4/25/77 @ 1525 4/25/77 @ 1441	11.0 ± 1.8	9 ± 10
6	Warehouseman	4/25/77 @ 1001 4/25/77 @ 0917	7.2 ± 1.4	12 ± 10
7	Package Oper.	4/26/77 @ 1038 4/25/77 @ 0917	11.9 ± 1.6	5 ± 10
8	Rip Operator	4/25/77 @ 1454 4/25/77 @ 1310	13.2 ± 2.2	-ND-
9	Maintenance	4/26/77 @ 0921	2.4 ± 1.4	-NC- (2)
10	Laborer	4/25/77 @ 1742 4/25/77 @ 1700	4.4 ± 0.8	0 ± 9
11	Maintenance	4/25/77 @ 1224 4/25/77 @ 1141	8.9 ± 1.8	3 ± 10
12	Maintenance	4/25/77 @ 0913 4/25/77 @ 0831	9.8 ± 1.8	10 ± 8
13	Chem Lab	4/25/77 @ 1054 4/25/77 @ 1010	9.6 ± 1.8	-ND-
14	Leach Operator	4/26/77 @ 1154 4/26/77 @ 1233	9.7 ± 1.6	10 ± 9
15	Mill Foreman	4/25/77 @ 1655 4/25/77 @ 1611	5.3 ± 0.8	16 ± 12

Table 1
Company I
In Vivo Counting Results

16	Rip Operator	4/26/77 @ 1308	1.0 ± 0.8	
		4/26/77 @ 1125		13 ± 8
17	Leadman	4/25/77 @ 1826	2.8 ± 0.6	
		4/25/77 @ 1743		-ND-
18	EPR Operator	4/26/77 @ 0725	3.6 ± 0.8	
		4/26/77 @ 0700		13 ± 9
19	Shifter	4/25/77 @ 0830	9.8 ± 1.2	
		4/25/77 @ 0747		11 ± 9
20	Leadman	4/26/77 @ 0845	5.9 ± 1.0	
				-NC-
21	Rad. Supv.	4/26/77 @ 0802	13.4 ± 2.6	
				-NC-
22	Mechanic	4/26/77 @ 1118	6.0 ± 0.7	
		4/26/77 @ 1152		-NC-

(1) Not Detectable
(2) Not Counted

Table 1 , Continued
Company I
In Vivo Counting Results

Company	Number of Observations	Population Arithmetic Mean ± 1-Sigma, mg	Average 2-Sigma Measurement Error, mg	Range, mg	Number of Observations	Geometric Median and Standard Deviation, mg
A	9	4.2 ± 2.8	± 1.1	0.8 TO 10.1	9	3.4, 2.2
B	14	7.1 ± 2.2	± 1.8	4.0 TO 11.0	14	6.8, 1.4
C	13	4.9 ± 3.3	± 1.2	1.5 TO 12.9	13	4.0, 2.0
D	12	3.0 ± 1.4	± 1.1	1.7 TO 6.8	12	2.7, 1.5
E	18	3.6 ± 1.9	± 1.1	0.8 TO 7.3	18	3.1, 1.9
F	20	8.9 ± 3.0	± 2.0	3.0 TO 14.0	20	8.3, 1.5
G	13	3.0 ± 2.1	± 1.2	0.8 TO 8.6	13	2.5, 1.9
H	10	4.2 ± 4.2	± 1.0	0.8 TO 15.1	10	3.0, 2.3
I	22	7.7 ± 3.7	± 1.4	1.0 TO 13.4	22	6.6, 1.9
Grand Mean or Median						
	131	5.6 ± 3.5	± 1.3	0.8 TO 15.1	131	4.4, 2.1

Note: The maximum permissible lung burden for natural uranium is 26 milligrams (Ref. 2).

Table 2
Natural Uranium in Lung Detected by Measuring 234-Thorium Daughter of 238-Uranium

Company	Number of Observations	Population Arithmetic Mean ± 1-Sigma NcI	Average 2-Sigma Measurment Error, NcI	Range, NcI	Number of Observations	Geometric Median and Standard Deviation, NcI
A	9	2.0 ± 2.5	± 10	0 TO 6	6	2.2, 2.4
B	14	6.5 ± 2.7	± 7	1 TO 10	14	5.6, 1.8
C	14	9.0 ± 12.1	± 10	0 TO 43	11	7.5, 2.5
D	12	5.5 ± 2.3	± 9	1 TO 9	12	4.9, 1.8
E	18	16.4 ± 6.5	± 9	0 TO 30	14	16.7, 1.3
F	19	5.5 ± 5.9	± 6	0 TO 18	14	6.0, 2.3
G	13	9.9 ± 7.4	± 10	1 TO 29	13	7.0, 2.7
H	10	11.0 ± 10.0	± 10	6 TO 24	7	14.5, 1.7
I	18	5.7 ± 5.9	± 10	0 TO 16	11	7.7, 2.3
Grand Mean or Median						
	127	9.1 ± 8.9		0 TO 43	108	7.6, 2.5

Note: The maximum permissible body burden for industrial workers is 100 nanocuries.

Table 3
226-Radium Results in Whole Body Determined by Least Squares Analysis

	Summary	Number of Observations	Population Arithmetic Mean ± 1-Sigma, mg	Geometric Median and Standard Deviation, mg	Range, mg
1	Filter Operator	5	10.0 ± 4.4	8.84, 1.87	3.0 TO 14.0
2	Yellow Cake Operator	13	8.4 ± 2.8	8.00, 1.46	4.0 TO 12.0
3	Lab Tech	10	6.3 ± 4.4	5.17, 1.91	1.8 TO 13.4
4	Management	21	5.1 ± 3.4	4.03, 2.11	0.8 TO 13.0
5	Maintenance	24	5.1 ± 2.8	4.34, 1.82	1.5 TO 10.7
6	Miscellaneous	13	5.0 ± 2.7	4.26, 1.96	0.8 TO 11.0
7	Operator	28	4.9 ± 3.4	3.89, 2.01	1.0 TO 15.1
8	Crusher	8	5.0 ± 3.8	3.69, 2.47	0.8 TO 12.0
9	Shifter	4	4.8 ± 4.1	3.19, 3.09	0.8 TO 9.8

Note: The maximum permissible body burden for industrial workers is 26 milligrams.

Table 4
Natural Uranium Results by Job Title

Because of the low levels of activity deposited in the workers' bodies and the very high backgrounds due to the mill environment, data reduction involved complicated subtraction and curve fitting techniques. Corrections were made for cosmic ray interferences which are significant at the high altitudes where the mills are located.

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Original Signed By
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Saul Levine, Director
Office of Nuclear Regulatory Research

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