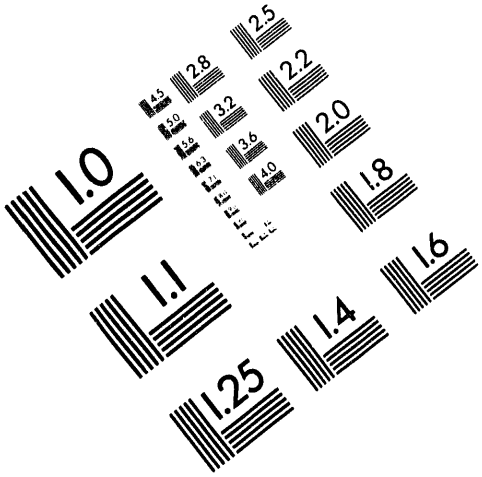

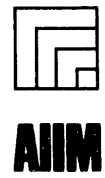

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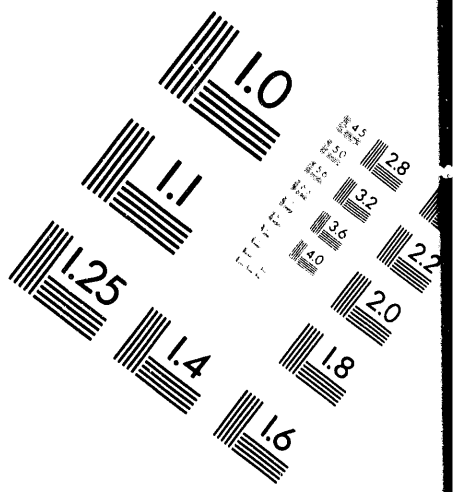

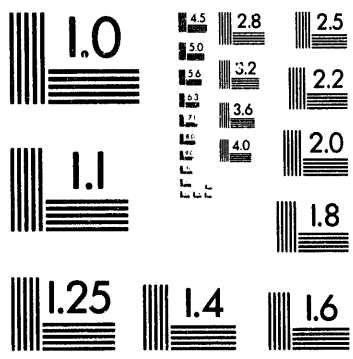

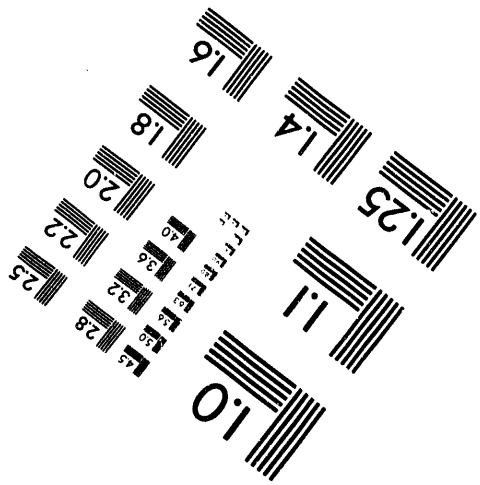

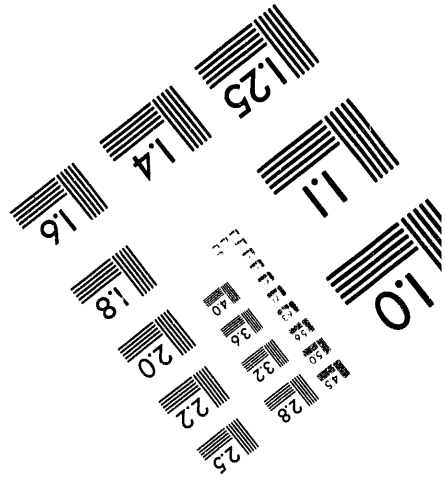

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A FEASIBILITY STUDY OF WORK GROUP MONITORING FOR HANFORD

J. A. MacLellan

April 1994

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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SUMMARY

Present Hanford internal dosimetry policy recommends placing a worker on a routine bioassay monitoring program if the 50-year committed effective dose equivalent (CEDE) in a single calendar year may exceed 100 mrem for all radionuclides.[a] Nearly all Hanford workers who enter contamination zones are on routine bioassay programs. Site environmental restoration and remediation now require an even larger number of workers to enter contamination zones, therefore increasing the number of workers requiring routine bioassay monitoring.

After evaluating the exposure potential for these workers, the Hanford Internal Dosimetry staff at Pacific Northwest Laboratory has recommended that large groups of workers not be included in routine bioassay monitoring. Work group bioassay monitoring has been proposed as a supplement to the present individual-specific monitoring program.

Work group bioassay is a method which demonstrates, at a reduced cost, that workers who are assumed to be essentially at no risk for incurring intakes are, in fact, not incurring intakes. For the proposed program, a work group will be identified by a letter to their exposure history file. The analytical result for a work group bioassay sample will be placed in the dosimetry record of the person actually providing the sample and will be identified as pertaining to a work group by an appropriate code. Any positive result will be followed up using the same procedure as for individual-specific bioassay, which limits false positives to less than 0.5%. Workers who 1) have radioactive material depositions that interfere with detecting and assessing additional intakes, 2) use any form of respiratory protection, or 3) enter airborne radioactivity areas will be excluded from a work group bioassay program and placed on an individual-specific bioassay program.

In practice, workers who have significant potential for exposure to transuranics would not be placed on a work group bioassay program. If a member of a work group is determined to have a confirmed intake of radioactive material, the internal dose associated with that intake will be included in the internal dose record for every other member of the work group unless additional bioassay monitoring can verify that the other members of the work group did not have an internal deposition. If during any year the CEDE for any member of the work group is greater than 100 mrem, the work group will be eliminated and individual-specific monitoring will be instituted.

(a) This work is supported by the U.S. Department of Energy under Contract DE-AC06-76RLO-1830.

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1.0 INTRODUCTION

Pacific Northwest Laboratory (PNL) investigated the feasibility of operating a work group bioassay program at Hanford, addressing criteria for applying work group sampling and logistics for operation at Hanford. Work groups are made up of workers who perform approximately the same tasks in approximately the same locations. Work group bioassay is a method which demonstrates that workers who are assumed to be essentially at no risk for incurring intakes are in fact not incurring intakes. Work group bioassay would be used as a supplement to individual-specific bioassay.

Individual-specific bioassay was historically, and is currently, conducted at Hanford and would continue to be required for workers requiring bioassay monitoring, as established by the *Hanford Site Radiological Control Manual* (RL 1992). Work group bioassay would apply to workers for which individual-specific bioassay is not required, but where some proof that the workers did not incur intakes is necessary. Work group sampling is a reduced-cost method of bioassay monitoring for workers with a low-dose potential.

Bioassay is defined by the National Council on Radiation Protection and Measurements (NCRP 1987) as "the determination of the kind, quantity, location, and/or retention of radionuclides in the body by direct (in vivo) measurement or by in vitro analysis of material excreted or removed from the body." Bioassay data provides the last available measurement of the adequacy of worker protection against internal radiation exposure.

In general, bioassay procedures are used to

- determine whether an individual has received an internal deposition of radioactive material and, if so, to quantify the magnitude of the deposition and its dosimetric consequences
- give baseline data and provide useful background information on exposures that might have occurred in past occupational assignments
- provide important input to evaluations of the extent to which the individual is adequately protected, is observing safe working practices, and is avoiding the accumulation of internally deposited radionuclides by means of routine scheduled measurements that are performed periodically after an individual is on the job
- document the estimated body or organ burden at the time a worker terminates employment
- aid in the medical evaluation and management of potentially over-exposed individuals.

For many of these uses, the documenting of no indicated internal deposition is just as important as identification of an internal deposition. The reason that this documentation is of such importance is because exposure monitoring is used to provide a legal record of exposure levels associated with various facilities and procedures.

Present Hanford internal dosimetry policy specified in the *Hanford Internal Dosimetry Project Manual* (Carbaugh et al. 1989) recommends placing a worker on a routine bioassay monitoring program if the 50-year committed effective dose equivalent (CEDE) from a single or multiple intakes within a single calendar year may exceed 100 mrem for all radionuclides. For planning purposes, a 100-mrem CEDE is considered to correspond to chronic exposure for one year to 2% of a derived air concentration (DAC), an acute or chronic intake equal to 2% of an ALI, or a time-integrated exposure to airborne contamination of 40-DAC hours. This is not always true but it provides a conservative presumption.

In the past, nearly all Hanford workers who were authorized to enter contamination zones were considered at risk for receiving a 100-mrem CEDE and, therefore, were included in a bioassay monitoring program. Site environmental restoration and remediation now require a greater number of workers to enter contamination zones. These workers should, therefore, be considered for routine bioassay monitoring (even though many of these zones have only low levels of contamination and little or no plutonium and other transuranics). After evaluating the exposure potential for these workers, the Internal Dosimetry staff have recommended that large groups of these workers not be included in routine bioassay monitoring. Although such recommendations confirm existing U. S. Department of Energy (DOE) regulations, they may have been perceived as departures from the established correlation of bioassay monitoring with contamination-zone work.

Work group sampling is a form of monitoring that documents low levels of intake and could eliminate unnecessary sampling and provide adequate assurance of worker safety. However, would work group sampling be feasible at Hanford? The remaining sections (Sections 2.0, 3.0, 4.0, and 5.0) address the following questions: Would work group sampling satisfy the relevant regulations on bioassay sampling? Do other DOE laboratories have experience in similar programs? Finally, what are the provisions and ancillary considerations in establishing a work group sampling program that would be effective at Hanford?

2.0 REGULATORY CONSIDERATIONS

It is the policy of the Hanford Internal Dosimetry Project to comply with DOE Orders, and to follow, to the extent practical, the guidance and good practice recommendations issued by national and international organizations.

2.1 DOE Radiological Control Manuals

The DOE *Radiological Control Manual* (DOE 1992) and the *Hanford Site Radiological Control Manual* (RL 1992) specify in Article 522 that baseline and periodic bioassay monitoring shall be conducted for all personnel who are likely to receive intakes resulting in a greater than 100-mrem CEDE. The intent of this requirement is further detailed in Article 521.1 (RL 1992), where it states, "In general, overly conservative use of bioassay monitoring... is discouraged; however, if the above guidance does not appear to adequately apply to a particular task, the company internal dosimetry organization shall be contacted for specific guidance." The discussions of this document apply to the case where CEDE is not expected to be greater than 100 mrem, but the potential for some exposure to internal depositions may warrant a special bioassay program.

2.2 National Council on Radiation Protection and Measurements

The guidance provided by the NCRP (1987) states that if the concentration of radionuclides in a workplace is normally very low, not all members of the work group need to participate in bioassay monitoring. The representative air sample results, averaged over a month, are usually considered an adequate basis for decisions on participation. For most work with long-lived, well-retained radionuclides, all workers should participate in bioassay monitoring at least once each year.

The primary criteria for implementation of a work group monitoring program pertain to the work place air sampling results. The time-weighted monthly average of air samples should result in 10% or less of the maximum permissible concentration (MPC) or the DAC, and the largest result used in the calculation of the time-weighted monthly average should be less than 30% of the MPC or DAC. At these levels, radionuclide confinement may be considered sufficiently effective and would require participation in the bioassay program only by a representative sample of the exposed personnel (i.e., the work group).

The individuals in a work group monitoring program who actually submit bioassay samples should be the most highly exposed or potentially exposed workers within a given area, and the work group should include at least 10% of the workers who have regular job assignments in the area (if the total number of workers is 100 or more). If possible, all members of the work group who are subject to similar potential exposures should be rotated through the program. If the total in the work group is between 10 and 100 workers, there should be at least 10 participants. For 10 or fewer workers, each worker should participate. Likewise, if the time-weighted monthly average of air sample results is much greater than 10% of the MPC or DAC, and/or the largest result used in the calculation of the average is greater than 30% of the MPC or DAC, all personnel whose regular job assignments involve work in these areas should participate in the bioassay program. Supervisory personnel and other observers who spend less than 25% of the work week in an area where bioassay is required should participate on a limited basis. The degree of participation is a matter of professional judgment of the bioassay program administrator.

Although work group sampling does not indicate the protection levels afforded individual workers, its use can provide additional information on the adequacy of radiological control measures in a facility, which is similar to general area air sampling. It is also useful in providing a legal record of exposure for workers with little potential for intake.

3.0 PRESENT BIOASSAY PROGRAMS AT OTHER DOE SITES

An informal telephone poll of internal dosimetry personnel at other DOE sites did not discover any other implementation of work group sampling. The Westinghouse Savannah River Site (SRS), however, has considered such a program and has included design criteria in their *Internal Dosimetry Technical Basis Manual* (SRS 1990).

Under the SRS work group monitoring plan, a fraction of the workers in the work group would be monitored at a frequency where an intake that would deliver 100-mrem CEDE would be detected. The program was not designed to identify individuals who exceeded 100-mrem CEDE, but rather to sample a group of workers that is unlikely to be exposed to radioactive materials. If any member of the work group has an intake of radioactive material, then all members of the work group would be placed on an individual-specific bioassay program.

Following NCRP recommendations, 10% of each defined work group, which is composed of 100 or more workers, would be sampled at a frequency of not less than once a year. Work groups composed of 11 to 100 workers would have 10 workers monitored, and all workers in work groups composed of 10 or fewer workers would be monitored.

Workers who have radioactive material depositions that interfere with detecting and assessing additional intakes, who use any form of respiratory protection, or who enter airborne radioactivity areas would be excluded from a work group bioassay program and would be placed on a routine bioassay program. In practice, workers who have significant potential for exposure to transuranics would not be placed on a work group bioassay program. The biokinetic models used would depend on whether chronic or acute exposures are anticipated.

4.0 WORK GROUP SAMPLING PROPOSAL

The following work group sampling proposal was developed to address the need for bioassay monitoring of work groups not expected to receive more than 100-mrem CEDE, but for which some biological measurement of a lack of intake is desired.

4.1 Establishing a Work Group

For the purposes of this proposal, a work group consists of 12 or more workers who perform approximately the same tasks in approximately the same locations. A primary assumption of work group sampling is that the entire work group has approximately the same exposure potential for internal dose. Without this assumption, a bioassay sample from one worker cannot be considered representative of other workers' exposures. If a worker is not a member of a group of 12 or more, any bioassay monitoring shall be individual-specific. Establishing the work group and identifying the members of the work group shall be the responsibility of the Hanford contractor dosimetry organization, in collaboration with the PNL Internal Dosimetry Project staff.

The expected annual intake potential for any group participating in a work group sampling program shall be less than 100-mrem CEDE, based on air sampling data, contamination control history of the facility, and guidance provided in Tables 5.1 and 5.2 in the *Hanford Site Radiological Control Manual* (RL 1992). According to the *Hanford Site Radiological Control Manual*, other factors that preclude participation in a work group sampling program include work that requires use of a respiratory protection device, or work that occurs in a high contamination area and involves contact with or disturbance of the contaminated material. The biokinetic models used to evaluate the internal dose to the work group shall depend on whether chronic or acute exposures are anticipated.

In addition to the radiologic dose, exposure to soluble forms of uranium (natural, depleted, or slightly enriched) also presents a risk from chemical toxicity. Calculations based on information from Sula et al. (1991) indicate the chemical "no-effect" thresholds for exposure to soluble uranium correspond to about 30-mrem CEDE for acute exposures and about 70-mrem CEDE each year for chronic exposures. Bioassay monitoring programs at Hanford for these compounds have, therefore, been implemented for workers with expected doses far below the 100-mrem limit. History has shown that the chemical toxicity limits have not been approached, and implementation of a work group monitoring program for these workers may be considered. Almost assuredly, any intake that would approach the threshold for toxicity would be discovered by workplace monitoring, which would lead to prompt special bioassay.

4.2 Work Group Bioassay Monitoring

Prior to inclusion in a work group, a worker shall be monitored for the same radionuclides that will be monitored in the work group. A worker shall not be included in a work group if any excretion of radioactive material is confirmed in the baseline sample. The criteria for selection of nuclides for work group bioassay monitoring shall be the same as for individual-specific bioassay monitoring, and the work group bioassay monitoring shall be scheduled regularly throughout the year.

For work groups of 120 or fewer members, 12 individual members shall be monitored each year (one worker will be monitored each month). For work groups of more than 120 members, at least 10% of the members shall be monitored each year. The workers initially monitored shall be those with the highest potential for exposure, and for each new year, the monitored members of the work group should be rotated. All members of the work group should be rotated through the monitoring program, but preference may be given to more frequent monitoring of those with the highest exposure potential.

4.3 Work Group Follow-Up Sampling

A positive result shall be followed up using the same procedure used for individual-specific bioassay. If this procedure results in a confirmed intake, the entire work group shall be assumed to have experienced the same intake until it is proven otherwise by additional bioassay sampling.

The contractor dosimetry organization will be required to establish the extent of the exposure. If the timing is such that an intake would no longer be detectable in other members of the work group, the intake shall be assigned to all members of the work group. If detection is feasible, additional monitoring will be conducted for other members of the work group who worked with the individual with the confirmed intake. Results from this additional monitoring may be used to adjust the estimate for the work group intake and may also be used to limit the individuals included in the exposed population.

4.4 Work Group Internal Dosimetry Records

A letter, initiated by contractor dosimetry, shall be placed in the dosimetry history file of each worker included in a work group. The letter shall include the identifier code for the work group and the date that the worker was included in the group. When the worker is removed from the work group, a similar letter shall be placed in the worker's dosimetry history file. Each worker in a work

group shall also be identified in the radiological exposure database (REX) using the identifier code. Each bioassay result for data collected in conjunction with a work group shall be placed in the dosimetry record of the person actually providing the bioassay sample. The result shall be identified as pertaining to a work group by an appropriate reason code. The reason code shall be designated as "W#," where "#" is the work group identifier code.

If a member of a work group is determined to have a confirmed intake of radioactive material, the internal dose associated with that intake will be included in the internal dose record for every other member of the work group unless additional bioassay monitoring can verify that the other members of the work group did not have an internal deposition. Any internal dose calculated for the work group shall be placed in the INTERTRAC portion of REX for each member of the work group. The intake mode designation shall be "WB#," where the "#" is the work group identifier. The internal dose evaluation report for the work group shall also be referenced in each worker's historical file. If it is determined that only a few members of the work group have had an intake, they shall be treated separately from the work group, and their bioassay data will not be representative of the entire work group. If during any year the assigned CEDE for any member of the work group is greater than 100 mrem, the work group will be eliminated and individual-specific monitoring will be instituted.

At the end of each calendar year, the bioassay data for the work group shall be gathered into a single list, and a letter that includes this list of bioassay data will be placed in each worker's historical file. The letter shall also include either the CEDE for the work group or a statement that all bioassay results for the work group were below applicable screening levels.

5.0 CONSIDERATIONS FOR IMPLEMENTATION

The following topics must be evaluated by the contractor dosimetry organizations prior to implementing any work group monitoring program.

5.1 Potential Savings

Potential cost savings will vary according to the size of the work group and the unit price of the analytical test. For an analytical test of unit price P, a work group of size N, and a sampling frequency of F samples per year per person, bioassay costs (C_{IS}) may be calculated as follows:

$$C_{IS} = N \times P \times F \quad (1)$$

If M is the number of individuals in the work group who are monitored, then the annual cost of work group sampling (C_{WG}) may be calculated as follows:

$$C_{WG} = M \times P \times F \quad (2)$$

The savings, as a percent of the individual-specific program cost, are then

$$Percent\ Savings = \left(\frac{(N \times P \times F)-(M \times P \times F)}{(N \times P \times F)}\right) \times (100) \quad (3)$$

$$Percent\ Savings = \left(\frac{(N - M)}{N}\right) \times (100) \quad (4)$$

The percent saving is independent of the unit price and is related to the work group size. The potential percent savings after initiating a work group sampling program for work groups of varying sizes are shown in Table 5.1.

TABLE 5.1. Potential Savings with Work Group Sampling

	Individuals Monitored		
Work Group Size	Criteria	Number	Potential Savings
12	12	12	0%
20	≥12	12	40%
50	≥12	12	76%
100	≥12	12	88%
120	≥12	12	90%
150	≥10%	15	90%
200	≥10%	20	90%

The additional administrative costs associated with establishing and operating the work group sampling program must be subtracted from these savings.

5.2 False Positives

The underlying assumption for work group bioassay sampling is that the work group is not actually exposed to significant intake of radioactive material, and monitoring a fraction of a work group will provide a record of the nonexposure at a smaller cost than an individual-specific bioassay monitoring program. Unfortunately, the reality of radiochemical analysis is that up to 5% of the analytical results from the bioassay samples submitted to the analytical contractor will meet the criteria for positive indication of the presence of radioactive material, even if these samples are collected from a nonexposed population (false positives). This is a result of random statistical fluctuations in the measurement parameters and cannot be decreased without a corresponding decrease in the sensitivity of the process. The work group bioassay program design must consider these random statistical fluctuations.

The normal procedure for evaluating a positive excreta bioassay result near the decision level is to recount the sample at least once. If the first recount is positive, the original count is confirmed. If the first recount is negative, a second recount is performed. If this recount is positive, the original count is confirmed; otherwise, the original count is considered to be a false positive.

Given that each count is independent and the probability of a false positive is 5%, the statistics of the recount process are as follows:

$$P\ (\textit{Second False Positive}) = 0.05 \tag{5}$$

$$P\ (\textit{Negative then Positive Follow-ups}) = 0.95 \times 0.05 = 0.0475 \tag{6}$$

$$P\ (\textit{Confirmed, Given Initial False Positive}) = 0.05 + 0.0475 = 0.0975 \tag{7}$$

The probability that the follow-up procedure will accurately discriminate against false positives is found as follows:

$$P\ (\textit{Two Negative Follow-ups}) = 0.95 \times 0.95 \tag{8}$$

$$P\ (\textit{Not Confirmed, Given Initial False Positive}) = 0.9025 \tag{9}$$

With this follow-up procedure, only about 0.5% (5% X 9.75%) of the analyses will be confirmed as positives when no radioactivity is actually present.

Although false positives for most bioassay procedures are adequately controlled using statistical considerations, some bioassay analyses require special procedures. Uranium, which is normally measurable in excreta, has an environmentally derived source, and a confirmed positive result is not a definite indication of an occupational intake. Therefore, screening levels have been established for uranium, below which an environmental source is assumed. Although the statistical distribution of the daily uranium excretion rates for the Hanford worker population have not been rigorously defined, only about 1% of the results are expected to exceed the screening level.

Because in vivo bioassay can detect the radiation emissions from many radionuclides at one time, the spectral regions of interest must be considered as a whole. To limit the false positives to 5% overall, the acceptable limit for false positives in a region of interest is reduced to 0.43% for the whole body counter. If a whole body count results in a measured quantity in excess of the decision

level, it is followed with a second count. If both of these are positive, a third count is done with a more sensitive system. The probability of confirming the presence of activity in the subject when no activity is actually present is literally less than one in a million with this procedure. However, there is a 5% probability of the more sensitive system giving a false positive result for some other nuclide which would then also require follow-up.

All bioassay analysis samples are vulnerable to interference from external contamination after collection. Because the contaminating activity in the sample did not result from an intake by the worker submitting the sample, such a result is a "false positive" even though there truly is activity in the sample. Recounting the sample will not identify the false positive, and extensive sampling of the individual submitting the sample and other work group members may be required.

With an individual-specific bioassay program, false positives affect the dose for only the individual. With a work group program, the dose for the whole group is affected unless additional samples can verify that the other members of the work group did not have an intake of radioactive material. If only a few mrem of internal dose are calculated, assigning the dose to each member of the work group will probably be acceptable. If the dose is approximately 100 mrem, it is more likely that the contractor dosimetry organization will want to sample more members of the work group to rule out intakes. This additional sampling will reduce the actual savings from implementation of the work group monitoring program. For a work group of 50 or larger, the additional monitoring to rule out false positives should never eliminate the savings when averaged over five or more years.

5.3 Work Group Bioassay Program Exclusions

Because chest counts are intended to detect the intake of transuranics, worker chest counts are not appropriate for work group monitoring. Work group monitoring shall also not include analysis for natural uranium with the standard uranium mass procedure until after a study of ambient background levels for Hanford workers adequately defines an appropriate screening level for that analysis. A work group monitoring program incorporating monthly sampling and the QUS analysis is acceptable when the higher detection level of that analysis is appropriate.

5.4 Work Group Bioassay Program Candidates

Although identifying work groups would be the responsibility of the contractors, a few potential work groups have been considered. The largest group consists of the environmental restoration and remediation workers previously mentioned. These workers are involved with the

sampling and excavation of large quantities of contaminated or potentially contaminated dirt. The soil involved may range from essentially uncontaminated overburden at burial grounds, to soil contaminated with a wide range and magnitude of radionuclides at liquid effluent disposal sites, such as cribs or ponds. In addition, future work may include intentional excavation of highly contaminated objects or accidental intrusion into contaminated burial boxes or barrels. Work group monitoring could be used to monitor environmental restoration and remediation workers not expected to exceed the individual-specific criteria given in a letter report on bioassay criteria for these workers (Cabaugh and Bihl 1993). For work group sampling to be effective in these circumstances, it will be imperative that workers exposed to soil concentrations above the criteria have special bioassay measurements performed promptly after the exposure. Persons knowledgeable of soil concentrations should be aware of the need for prompt notification of contractor dosimetry when criteria have been exceeded.

Potential work groups may also include the office and clerical staff at the 234-5Z Facility Plutonium Finishing Plant, supervisory personnel, and workers at the 100-KE Fuel Storage Basin. Recent data suggests that the ratio of cesium to strontium is closer to one; in past years, data indicated that the ratio was much less than one, which would have made a monitoring program based entirely on whole body cesium measurements unable to detect strontium uptakes at the required control level. Presently, however, work group monitoring of strontium excretion could be used to supplement the cesium whole body counts and to validate the adequacy of the monitoring program.

6.0 CONCLUSION

Work group monitoring may be a viable alternative to individual-specific monitoring for a limited number of workers at Hanford. Implementation will require a joint effort of Internal Dosimetry Project staff and contractor dosimetry organizations.

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