EGG-M-21582
PREPRINT

NRC Research and/or Technical Assistance Report

Guidance for Air Sampling at Light Water Reactors

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October 12-15, 1982

Tenth Water Reactor Safety Research
Information Meeting

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1. PURPOSE OF WORK

We have been contracted by the NRC to perform an assessment of radiological air sampling programs, and provide guidance for improving these programs. Air sampling programs help provide for worker safety, and are useful for demonstrating compliance with federal regulations for protection against airborne radioactive material (10 CFR 20). Worker protection is the major goal for safety professionals at NRC sites, and ideally the primary design objective for air sampling programs is to assist safety professionals in providing safe working conditions. In reality, the choice of methods for monitoring airborne activity at NRC facilities is strongly influenced by the method of dose assessment and means for demonstrating compliance which are specified in 10 CFR 20.

Much of the recent interest in air sampling has been generated because of the possible revision of 10 CFR 20. This revision may incorporate some of the elements of the ICRP 26, 30 dosimetry system, and may change the choice of methods used by licensees for internal dosimetry.

Current 10 CFR 20 and DOE regulations use critical organ dose as the dose limiting yardstick, and bioassay is specified as the means of determining organ dose. The proposed revision of 10 CFR 20 will allow air sampling measurements as a basis for estimating intake and calculating internal dose. This approach to internal dosimetry will require far more accurate, representative sampling of air breathed by individual workers than is possible with most current air sampling systems.

The NRC recognizes that accurate individual intake estimates are essential for successful application of the proposed 10 CFR 20 regulations. This work is part of an effort to determine if the licensee air sampling programs are adequate for monitoring individual intake. Information gathered from a literature review, worksite visits, and equipment tests will provide an insight into the present status of air sampling and the possibility of improving the programs with new technology and improved methods.

Personal air samplers (PAS) are being considered as a means of improving air sample representativeness for measuring individual intake, although it is not established that PAS would be adequate for this purpose. There is an extensive collection of literature dealing with applications of personal air sampling. Some of these articles describe differences between exposure estimates obtained using personal air sampling and general area air sampling. The research indicated that underestimates of exposure by large factors (up to 100 or more) were possible when using general area air sampling. This early work is of particular interest in view of the proposed use of air sampling for dose assessment.

Our recommendations for improvement of air sampling programs will be useful even if the proposed 10 CFR 20 is not adopted. At present, many radiological safety programs use air sampling and bioassay together, with the assumption that intakes will be detected by at least one of the two methods.

This is done with the understanding that licensees "Shall as appropriate use... (bioassay)...for timely detection and assessment of individual intakes of radioactivity by exposed individuals." Radiological safety personnel using air sampling in coordination with bioassay to satisfy these requirements are obligated to establish that their air sampling system is at least capable of detection of individual exposure incidents, to ensure that bioassay is performed in a timely manner.

If MPC-hrs are used as the functional equivalent of internal dose estimates, as is often the case, then there should be some reasonable basis for comparison, if not conversion, of MPC-hrs to dose equivalent. This use of air sampling data is similar to the intake to internal dose conversion (i.e., DAC-hrs to rem) proposed for 10 CFR 20.

2. RESEARCH PLANS AND RESULTS

The research planned for this project was designed to provide a basis for the recommendations and will include: (a) a review of literature, (b) surveys of visit to typical worksites, (c) equipment testing and evaluation, and (d) internal dosimetry evaluation. The product of this work will be a summary of findings, equipment and technique evaluations, and conclusions and recommendations for improving air sampling at nuclear facilities.

2.1 Worksite Studies

Worksite visits were planned for field characterization of airborne material, and to provide first-hand knowledge of working conditions. Each air sampling system will be evaluated with regard to its effectiveness for monitoring airborne contamination in the specific conditions which exist at that site. In principle, conditions (activity size distribution of the radioactive aerosol, containment, work procedures, etc.) at each worksite and the purpose for sampling (personnel exposure vs. area monitoring) define the performance requirements for an adequate air sampling system, and design of the system is directed towards meeting these requirements. We feel that any form of guidance for air sampling must include a recommendation that conditions at each site be considered and accommodated in system design; an inflexible form of "guidance" will certainly result in air sampling systems which are mismatched to the needs of the licensees.

In our research we have seen evidence that the current air sampling systems at uranium mills do not provide an adequate indication or measure of uranium intake by workers, although they are used to demonstrate compliance with regulatory limits. Air sampling at mills is usually done on a monthly schedule, in a number of work locations, with collection times as brief as 10 minutes. In almost all cases, total airborne uranium concentration (as opposed to the respirable uranium fraction) is used for calculation of MPC-hrs, as an indication that internal exposure limits had not been exceeded. The mills also use urinalysis as an alternate measure of internal exposure. As part of our field work we looked for, but found very little correlation between air sampling exposure estimates and bioassay results. While there is no reason to expect exact correlation, this does indicate that air sampling provides an incomplete evaluation of mill workers' exposure status.

One possible explanation for this poor correlation is the wide variability of activity concentration and dilution in the mill worksite. In most instances worker exposure is due to brief, point releases of contamination (a puff) generated as the result of the worker's own activity. Detection and quantification of the release of contamination by an area monitor is unreliable since the amount of dilution between the source and the monitor is quite variable. A number of researchers (at LANL and the AERE) have measured dilution factors at various work locations. Their results indicate a great potential for error when correlating worker exposure to general air sampling results. Improved sampling techniques may help eliminate some of this error.

There are a number of other sources of variability or error which could lead to a poor correlation between air sampling intake estimates and actual internal dose. Some of these are

- Unusually large or small respirable fractions of the inhaled dust. Our measurements and previous research indicate that mill aerosols have small respirable fractions. Size selective sampling may give better information for determining worker exposure.

- Unusual solubility characteristics of the inhaled dust. Results of solubility and chemical analysis of mill particulate samples taken during our work are not yet available, but will provide further information regarding correlation between worker internal exposure and air sampling.

° Variations in physiological response between individuals, and with respect to the standard man.

2.2 Air Sampling Equipment Performance Testing

Performance tests of air samplers are planned to determine the capabilities and relative merits of routine and special purpose samplers. The results of these tests will provide a basis for recommending equipment and methodology to incorporate in a sampling system. A useful air monitoring system may be developed using several types of samplers which, if used individually, would not provide adequate measurements for all purposes. We are restricting our testing to samplers which are in widespread use or which might easily be applied in widespread use. Exotic, "lab-bench" equipment will not be tested.

We have developed an aerosol generation and testing facility with capability for testing sampler response to monodisperse aerosols under controlled conditions. Generation of polydisperse aerosols from particles collected at NRC sites will be possible in the near future.

Air samplers will be tested for particle size dependent collection characteristics, wall losses in the cassette, and sensitivity to anisokinetic air sampling conditions.

We have conducted a detailed mechanical evaluation of commercially available PAS to determine if they would be acceptable for extensive, perhaps fulltime use as monitors of workers' exposure to airborne contamination. PAS performance was evaluated in three broad areas, mechanical performance, human engineering, and operating convenience. The best pumps we have tested would be suitable for use in an extensive PAS-based monitoring program.

We also planned to conduct testing of equipment in simulated working situations. An experiment has been conducted in collaboration with the Inhalation Toxicology Research Institute to determine the properties of aerosols generated during pipe cutting, simulating a decontamination and decommissioning operation. The aerosol was generated in typical work conditions, and several types of samplers were operated in the cutting room.

A worker was fitted with two PASs, sampling from his right and left lapels. Sampling took place while the worker cut pipe (as a simulation of a decommissioning operation). A factor of 3 difference in concentration was measured between right and left sampling locations, probably due to large aerosol concentration gradients and nonuniform mixing occurring in the vicinity of the point source (an electric arc cutting rod) of the aerosol.

Our work and the work of researchers over the past 20 years indicates that while PAS monitoring provides a <u>better</u> estimate of individual exposure, it is <u>not</u> consistently capable of accuracy within a factor of about 3, and may be inaccurate by even greater factors under less-than-ideal conditions (i.e., anisokinetic sampling due to air movement, resuspension of contamination from clothing, etc.).

2.3 Internal Dosimetry Evaluation

An evaluation of internal dosimetry is an implicit program objective. Bioassay has been the method of choice for internal dosimetry, and will probably have a substantial role in dosimetry requirements in the proposed 10 CFR 20. Bioassay and air sampling both have shortcomings as measures of internal dose, and the most effective internal dosimetry programs would use both in a complementary fashion. Air sampling is an attractive alternative to bioassay, particularly excreta analysis, because it is a relatively simple method to apply. However, the potential for error when estimating internal dose from air sampling measurements must be evaluated before acceptance of air sampling as a primary means of assessing internal dose. There may be circumstances where air sampling of any practical kind would be a poor basis for calculating internal dose. NRC licensees should be aware of this, and regulatory guidance for the proposed 10 CFR 20 should take into consideration the difficulty of obtaining air samples suitable for individual internal dosimetry.

3. PRELIMINARY CONCLUSIONS

One of the first and most important steps in planning an air sampling program is to clearly define the objectives of the program. Air sampling systems may be designed to meet either or both of two general objectives:

- Monitor the containment of contamination in the worksite, to check the effectiveness of physical contamination barriers and the effectiveness of job planning and standard procedures in limiting the spread of contamination.

- Provide information for estimating worker exposure. Air sampling may be used to help estimate exposure or potential exposure of workers. This information may be used for a number of purposes, including routine exposure assignments to demonstrate regulatory compliance or for exposure assessment in emergency situations to determine potential health effects. The exposure extimate may also be used to infer intake of radionuclides for internal dose assessment.

General area monitoring can be an effective means of checking containment of contamination. Sensitivity of area monitors is usually high and unusual measurements can be associated with a particular area.

PAS monitoring is superior to general area monitoring for estimating individual exposure, since it usually draws a more representative sample of air breathed by the worker. However, we conclude from research, field experience, and the literature review that even PAS is not a sufficiently reliable measurement technique for estimating an individual's internal dose.

Air sampling is probably best suited to characterizing airborne hazards, or as an alarm to indicate unusual conditions. These applications are consistent with the ALARA philosophy. Job planning for reduction of exposure requires accurate measurement of airborne activity, and an understanding of the limitations of the measurement technique. The most valuable product of this work may be guidance for applications of air sampling for ALARA job planning.