222
7-13-76
LA-6087

D. 142

UC-41

Reporting Date: September 1975

Issued: May 1976

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Respirable Concentration and/or Particle-Size
Characteristics of Aerosols**

by

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UNITED STATES
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
CONTRACT W-7405-ENG-36

MASTER

Work supported by US Energy Research and Development Administration,
Division of Operational Safety.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
Price: Printed Copy \$3.50 Microfiche \$2.25

SURVEY OF SAMPLING TECHNIQUES FOR DEFINING RESPIRABLE CONCENTRATION AND/OR PARTICLE-SIZE CHARACTERISTICS OF AEROSOLS

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ABSTRACT

A survey has been made of aerosol sampling procedures used by selected ERDA contractors. Of those responding to a questionnaire, approximately half performed respirable-dust sampling or aerosol size analysis. The wide variation in sampling devices, calibration methods, and data handling techniques indicates the need for standardization of aerosol sampling techniques. Results of the survey will be used in the forthcoming "Manual of Recommended Practice for Aerosol Sampling and Evaluation," to be prepared by the Los Alamos Scientific Laboratory under sponsorship of ERDA's Division of Operational Safety.

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INTRODUCTION

The concentration of toxic aerosols in the air of workplaces is a parameter of major concern to the health physicist and the industrial hygienist. Many aerosol samplers now commercially available are capable of separating airborne particles into respirable and nonrespirable fractions or of fractionating particles by particle size.¹ Results from a questionnaire sent to selected ERDA contractors have been used to (1) determine the extent to which these two aerosol sampling techniques are being used, (2) plan visits to those organizations with expertise in these techniques, and (3) determine the need for, and scope of, a proposed aerosol sampling procedures manual. Similar surveys of AEC licensees, ERDA contractors, and government radiological health agencies have been reported.^{2,3}

BACKGROUND

Two-stage aerosol samplers can be used to determine compliance with the cotton dust standard⁴ for

lint-free dust and when the Threshold Limit Value⁵ (TLV) or other standard is given in terms of respirable dust. Aerosols with TLVs in terms of respirable dust include quartz, silica flour, Tripoli, and coal containing <5% quartz. Two-stage samplers cannot be used to determine compliance with the TLVs for most toxic aerosols because (1) insufficient documented information exists for respirable-dust limits to be established, and (2) sampling for respirable dust is valid only for those aerosols which are insoluble or poorly soluble in the lung and body fluids and which exert their toxic effects in the alveoli over long retention times. Two-stage samplers can also be used to determine the potential danger from radioactive aerosols. Alpha emitters are of particular concern, because the alpha particle's short range restricts its effects to the area immediately adjacent to the deposited aerosol, and its high energy may adversely affect the tissues in that area.

The U.S. Atomic Energy Commission Rules and Regulations, Title 10 CFR 20.103 (c) (1970) stated:

"(1) Except as authorized by the Commission pursuant to this paragraph, no allowance shall be made for particle size or the use of protective clothing or equipment in determining whether an individual is exposed to an airborne concentration in excess of the limits specified in Appendix B, Table I.

"(2) The Commission may authorize a licensee to expose an individual in a restricted area to airborne concentrations in excess of the limits specified in Appendix B, Table I, upon receipt of an application demonstrating that the concentration is composed in whole or in part of particles of such size that such particles are not respirable; and that the individual will not inhale the concentrations in excess of the limits established in Appendix B, Table I. Each application under this sub-paragraph shall include an analysis of particle size in the concentrations; and a description of the methods used in determining the particle sizes." These regulations now apply to licensees of the Nuclear Regulatory Commission.

The Task Group on Lung Dynamics (TGLD) of the International Commission on Radiation Protection has reviewed extensive studies on the deposition and retention of aerosols in the human respiratory tract.⁶⁻⁸ On the basis of several assumptions, including the log-normal distribution of inhaled aerosols, the TGLD concluded that deposition is proportional to the aerosol's mass median aerodynamic diameter (MMAD). (A particle's aerodynamic diameter is defined to be equal to the diameter of a unit density sphere having the same settling velocity in air.) The quantity of aerosol collected by many two-stage samplers can be related to the pulmonary deposition as predicted by the TGLD by a simple fraction.⁹⁻¹¹

A general definition of respirable dust is that part of an aerosol that is likely to penetrate to and deposit in the pulmonary air spaces of the lung. Two specific definitions of respirable dust are also given in terms of the particle's aerodynamic diameter.

1. The British Medical Research Council⁸ (BMRC) defines the respirable fraction (RF) in terms of the relationship:

$$RF = 1 - \left(\frac{d}{7.1} \right)^2$$

where d is the particle aerodynamic diameter. (This definition limits respirable particles to those $< 7.1 \mu\text{m}$.)

2. The American Conference of Governmental Industrial Hygienists⁵ (ACGIH) includes 90% of particles $< 2 \mu\text{m}$, 75% of $2.5\text{-}\mu\text{m}$ particles, 50% of $3.5\text{-}\mu\text{m}$ particles, 25% of $5.0\text{-}\mu\text{m}$ particles, and no particles $> 10 \mu\text{m}$ in aerodynamic diameter.

This last definition supersedes an earlier one, frequently called the Los Alamos Scientific Laboratory

Fig. 1.
Standard curves defining respirable dust.

(LASL) curve, which included 100% of the particles $< 2 \mu\text{m}$ as respirable. The ACGIH modified the LASL curve to reflect the collection characteristics of actual sampling devices.

The BMRC definition for respirable dust is closely approximated by two-stage samplers in which a horizontal elutriator is used for the first stage, followed by a high efficiency filter. The LASL and ACGIH definitions are identical, for practical purposes, and are closely approximated by two-stage samplers in which a cyclone is used for the first stage, followed by a high efficiency filter. In both techniques, the respirable dust is collected by the second-stage filter, while the nonrespirable material is removed from the air stream by the first stage (Fig. 1).

Many commercially available air samplers can measure aerosol size distribution, but to be useful in hazard determination, or in selection of dust control equipment, the particle size distribution should be in terms of the aerodynamic diameter. Many instruments size aerosols on the basis of some other size parameter. In these cases, the results should be converted to aerodynamic diameter by appropriate instrument calibrations. Samplers that measure the aerodynamic diameter directly include multistage impactors, centrifugal sedimentation devices, settling chambers, graded filters, multirod rotary impactors, multicyclones, cascade centripeters, and horizontal elutriators.¹ Samplers measuring other parameters include all microscopic or light scatter methods, all beta, gamma, or x-ray scatter methods, electrical mobility devices, glow discharge perturbation devices, acoustic counters, hot wire anemometers, ionometric devices, alpha track methods, diffusion batteries, and the Coulter Counter.¹

The TGLD report⁶ includes a chart from which percentage of aerosol deposition can be found when the MMAD is known. For heterogeneous dusts containing mixtures of toxic and nontoxic materials, only the toxic part of the aerosol is important. Variations in minute volume (breathing rate) greatly affect the amount of dust deposited, but usually do not much affect the percentage of deposition. (An exception occurs in prolonged breath-holding, when almost all of the inhaled dust of every particle size will be deposited.) The TGLD provides tables, based upon the biological half-life of the deposited dust, from which the retention times for many materials can be calculated. The TGLD recommends that the particle size distribution by mass be obtained. The MMAD of this distribution can then be used in conjunction with the chart and tables to determine the amount of deposition and retention in the lungs.

METHODS

A questionnaire was designed to determine

- To what extent ERDA contractors use air sampling for respirable-dust determination or for particle size analysis.
- What sampling equipment and data analysis methods are currently in use.
- Which ERDA contractor facilities have sufficient sample volume and sampling expertise to warrant a study visit before preparation of a "Manual of Recommended Practice for Aerosol Sampling and Evaluation."

In September 1974, this questionnaire was mailed to 53 ERDA contractors and 9 government agencies (2 U.S. and 7 foreign). It was directed to the attention of individuals responsible for the health and safety of employees. In cases where separate industrial hygiene and health physics groups existed, two questionnaires were sent to the same facility.

RESULTS

Copies of the introductory letter, explanation of the survey, and the questionnaire are given in the Appendix of this report. Of the 53 ERDA contractors contacted, 37 (70%) replied.

Table I contains an overall summary of the questionnaire responses, without regard to the type of air sampling done at particular facilities. Thirty-two (86%) of those replying do aerosol sampling of one or more kinds. Seven (19%) use two-stage samplers to measure respirable dust, 22 (59%) use

size analysis samplers, and 29 (78%) analyze the entire dust sample. These numbers show an increase in the proportion of ERDA contractors using two-stage and size analysis samplers over that reported by Ettinger in 1969.³

In Table II, the data are arranged according to the three major types of size selective samplers. The number of facilities using each type of sampler is shown in the first line; the figures in each column headed "% of Replies" are based upon this number. There is some duplication, because many facilities use more than one type of sampler. Most size analysis sampling methods are used <10% of the time that sampling is performed. They are used most often for health risk evaluation; then, in decreasing importance, for evaluation of engineering controls, compliance with laws and regulations, exposure documentation, source identification, respirator selection, and investigation of complaints. Samples are taken most frequently from stacks; less frequently from area samples (delayed analysis), continuous monitors and personal samplers, breathing zone samplers, and emergency or indicating samplers.

Of those using respirable-dust samplers, 6 (86%) use cyclones and 1 (14%) uses an annular impactor. Of those using microscopic size analysis methods, 15 (100%) use both the impinger and filters to collect samples, and 1 (7%) uses the electrostatic precipitator in addition. Of those using size fractionating samplers, 9 (75%) use cascade impactors and 4 (33%) use light scatter devices.

Most facilities do not themselves calibrate their equipment so as to obtain the particle aerodynamic diameter, but use the manufacturer's recommendations or the technical literature for calibrations. Also, most do not correct their raw data for particle density, index of refraction, filter burial losses, or particle shape factors, where those corrections would be appropriate.

The most frequently used particle size distribution statistic is the geometric standard deviation. The most frequent measures of central tendency are the count median diameter (for those using microscopic analysis) and the MMAD (for those using size fractionating samplers).

The delay period between receipt of a requirement for sampling and completion of the analysis is not related to the type of sampler used. Most samples take two days or less to collect and analyze. The consensus among all facilities is that this delay has virtually no effect upon the ability of health and safety personnel to control exposures. The most significant effects appear to be delay of reports and, in some instances, the use of such conservative control measures as a requirement that respirators be worn in areas that might prove to have no aerosol

contamination were adequate sampling results available. Site visits made as a result of this survey indicate that the most frequent solution to the problem caused by this delay has been to install continuous air monitors with instant readout.

Table III is a summary of comments made by the questionnaire recipients regarding their feelings and suggestions about sampling problems that should be covered in the forthcoming "Manual of Recommended Practice for Aerosol Sampling and Evaluation."

DISCUSSION

Several points made in previous surveys³ have been confirmed in the present survey. These include:

- Results of surveys probably overestimate the frequency with which special sampling procedures are used, because those who do not reply probably do less sampling than those who do reply.

- Aerosol particle size determined by microscopic analysis, or light scatter devices cannot be readily related to the particle's aerodynamic diameter, which is the only parameter directly related to the probability of inhalation and to the performance of most air cleaners. (Airborne fibers, such as asbestos and glass, may be exceptions to this generalization.)

- Size analyses and respirable-dust sampling are most frequently done on nonradioactive aerosols. The respirable-dust concept inherent in assumptions used to set Maximum Permissible Concentrations (MPCs) for radioactive materials is generally ignored.¹²

- Specialized sampling procedures using size-selective devices may be more time-consuming than total air sampling, but provide the following advantages:

1. A quantitative estimate of the inhalation hazard can be made.

2. Engineering controls can be tailored to the specific aerosol hazard.

3. Contamination levels at different locations and at different facilities can be readily compared to determine hazardous conditions.

4. The inhaled-dose estimates can be better compared to the standards used to compute MPCs for radioactive materials. These MPCs were originally set by assuming that 25% of an inhaled aerosol was deposited in the lung initially and that 12.5% was retained in the lung for more than 24 h.

Samples from two-stage samplers are easier to collect and analyze than those from devices that determine an aerosol's aerodynamic size distribution. In addition, the cyclone two-stage sampler is available in a variety of flow rates. Assuming a log-normal size distribution, the mass of material

collected on the filter behind a cyclone or horizontal elutriator has a direct relationship to the lung deposition values defined by the TGLD lung model, as follows:

$$P = a + bK,$$

where P = penetration in percent, and K = concentration of fraction penetrating the first stage. Both P and K are functions of the aerosol's MMAD and geometric standard deviation. The value of a is close to zero, and b is approximately equal to 0.3, for both the cyclone and the horizontal elutriator.^{9,11}

Devices, such as cascade impactors, that fractionate aerosols on the basis of aerodynamic diameter require more effort during sampling and analysis, and may be more expensive than some two-stage samplers. However, they provide much more information in a form more readily usable for evaluations of worker's health risk, engineering controls, exposure documentation, and source identification. In addition, this particle size information can be used to compute collection efficiencies for any current or future models of lung deposition as well as collection curves for most control equipment.¹³

No attempt has been made in this report to give any guidance as to when a particular form of sampling should be done. If size selective sampling methods are used, however, then good practice should require use of the appropriate calibration methods, correction factors, and data handling techniques. It appears that the variations in use of these procedures, shown by the responses to the questionnaire, indicate the need for more standardization of aerosol sampling techniques. Standard procedures might vary for different operations and purposes of sampling, but would facilitate comparing results from similar operations at different facilities. A "Manual of Recommended Practice for Aerosol Sampling and Evaluation," is now being prepared in order to address these problems.

ACKNOWLEDGMENTS

We wish to express our appreciation to the ERDA contractors and government agencies that participated in this study. Without their assistance and cooperation, this work would not have been possible.

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APPENDIX

SUMMARY OF QUESTIONNAIRE RESPONSES

LETTER OF INTRODUCTION

Dear

The Los Alamos Scientific Laboratory, under sponsorship of the AEC's Division of Operational Safety, is preparing a "Manual of Recommended Practice for Aerosol Sampling and Evaluation." Aerosol sampling and sizing methods were previously surveyed and summarized in Report LA-4249 (Vol. I, 1969; Vol. II 1971). A re-survey is now being conducted because progress in the aerosol sampling field may have outdated the previous results.

We ask that you complete and return the attached questionnaire by October 9, 1974, in the enclosed stamped, self-addressed envelope. Replies will be treated as administrative confidential information. No report or manual derived from this information will list procedures used by any specific facility. Data obtained will provide a basis for the proposed Manual.

We welcome your comments and suggestions, and space has been provided for this purpose. Additionally, the author of the Manual should experience first hand the problems, conditions, and techniques of sampling at a variety of facilities. If a visit to your facility for this purpose could be arranged during the months of November or December 1974, please indicate in the space provided.

A discussion of the questionnaire goals is attached for your information.

Thank you for helping in this project to standardize air sampling procedures at AEC contractor facilities.

Sincerely,

PURPOSE OF THIS SURVEY

A. Survey Aim

Because of the importance of aerosol sampling and size characterization in estimating health hazards, implementing engineering controls, and documenting exposures, an effort is being made to achieve standardization of available techniques, and to resolve disagreements regarding the use and calibration of size selective samplers. This survey, and two previous surveys of this type, will provide a basis for developing a "Manual of Recommended Practice for Aerosol Sampling and Evaluation."

B. Background

To evaluate more accurately health hazards due to inhalation of toxic particulates, increased emphasis is being placed upon air samplers that separate airborne material into "respirable" and "nonrespirable" fractions, or that determine aerosol particle size characteristics.

A general definition of "respirable fraction" is that portion of inhaled particles that are most likely to deposit in the nonciliated pulmonary airspaces of the lung. The British Medical Research Council (BMRC) detailed this in terms of the particle's falling speed, so that the respirable fraction includes 95% of particles of 1.5- μm (aerodynamic diameter); 50% of 5.0- μm particles; and no particles greater than 7.1 μm . An alternate definition proposed at a Los Alamos Scientific Laboratory (LASL) Conference specified criteria based upon early inhalation data. The LASL model for the respirable fraction included 100% of particles smaller than 2.0- μm (aerodynamic diameter); 50% of 3.5- μm particles; and no particles greater than 10 μm . The "Threshold Limit Values for Chemical Substances and Physical Agents in the Workroom Environment with Intended Changes for 1974" published by the American Conference of Governmental Industrial Hygienists (ACGIH) definition for respirable dust differs only slightly from the LASL model. In the ACGIH model, only 90% of the particles less than 2.0- μm (aerodynamic diameter) are respirable.

In addition to these two-stage samplers, there are several ways of measuring aerosol size distributions, allowing calculations of the aerosol's "respirable fraction" based on one of the applicable models. One way to do this is to collect a representative aerosol sample for particle size analysis using the light or electron microscopes. Another way is to utilize one of the many devices capable of measuring directly either the particle's aerodynamic diameter, or some property of the particle which can be related to the aerodynamic diameter with suitable correction factors.

To aid in defining safe concentrations of radioactive aerosols, the TGLD Task Group on Lung Dynamics has specified the most refined lung model to date. The Task Group found that deposition could be adequately predicted by the aerosol mass median aerodynamic diameter (MMAD) or, for radioactive aerosols, by its activity median aerodynamic diameter (AMAD), when the aerosol was assumed to follow a log-normal distribution. This model specifies three respiratory compartments (nasopharyngeal, tracheobronchial, and pulmonary) and three classes of particles, based upon the biological half-life of the aerosol fraction deposited in the pulmonary compartment (Class D = 0 - 10 days, Class W = 10 - 100 days, Class Y = more than 100 days). This model deals with clearance mechanisms of four distinct pathways: direct absorption, rapid ciliary clearance to the gastrointestinal tract, slow ciliary clearance after phagocytosis via the gastrointestinal tract, and lymphatic clearance.

The U.S. A.E.C., in its Regulation 10 CFR 20, states that the limits specified in Appendix B, Table I, must be adhered to as maximum time weighted average, 40 hour per week concentrations of radioactive materials in air. It says:

"20.103 (a).... For the purpose of this regulation, it is assumed that an individual inhales radioactive materials at the airborne concentration in which he is present, unless he uses respiratory protective equipment pursuant to paragraph (c) of this section."

SAMPLE QUESTIONNAIRE

(Numerals in boxes indicate number of replies received.)

SURVEY OF AIR SAMPLING TECHNIQUES FOR DEFINING RESPIRABLE CONCENTRATION AND/OR PARTICLE SIZE CHARACTERISTICS

I. SAMPLING PROCEDURES

- A. Do you do any aerosol sampling? ☒ 38/ YES ☒ 5/ NO - Skip to section IV.
- B. Why do you sample? ☒ 26/ Exposure documentation ☒ 25/ Source identification ☒ 40/ Compliance with laws, regulations, etc.
☒ 36/ Health risk evaluation ☒ 19/ Respirator selection ☒ 22/ Evaluate engineering controls
☒ 17/ Investigate complaints ☒ 5/ Other (Describe) _____
- C. Do you use any of the following techniques? If NO, skip to Section II.

	2-Stage Samplers (Respirable and Non-respirable Stages)	Samplers for Microscopic Analysis of Particle Size	Samplers with Particle Size Discrimination
1. This technique?	☒ 10/ YES ☒ 18/ NO	☒ 20/ YES ☒ 12/ NO	☒ 17/ YES ☒ 17/ NO
2. How much of your aerosol sampling is done by this technique?	☒ 16/ 0-10% ☒ 3/ 26- 50% ☒ 0/ 11-25% ☒ 0/ 51-100%	☒ 10/ 0-10% ☒ 0/ 26- 50% ☒ 2/ 11-25% ☒ 4/ 51-100%	☒ 10/ 0-10% ☒ 0/ 26- 50% ☒ 1/ 11-25% ☒ 5/ 51-100%
Comments: _____	☒ 1/ Special problems only (Describe) _____	☒ 6/ Special problems only (Describe) _____	☒ 6/ Special problems only (Describe) _____
3. Primary use of this technique?	☒ 2/ Alpha ☒ 0/ Beta ☒ 0/ Gamma ☒ 7/ Non-radioactive (What?) _____	☒ 4/ Alpha ☒ 0/ Beta ☒ 0/ Gamma ☒ 18/ Non-radioactive (What?) _____	☒ 5/ Alpha ☒ 5/ Beta ☒ 4/ Gamma ☒ 5/ Non-radioactive (What?) _____
Comments: _____	_____	_____	_____
4. What kind and type of sampler?	☒ 8/ Cyclone type: _____ ☒ 2/ Elutriator type: _____ ☒ 2/ Other: _____ Type: _____	☒ 5/ Impinger type: _____ ☒ 19/ Filter type: _____ ☒ 3/ Other: _____ Type: _____	☒ 12/ Impactor type: _____ ☒ 6/ Light Scatter type: _____ ☒ 4/ Other: _____ Type: _____
5. Calibration or analysis method?	☒ 2/ Manufacturer ☒ 3/ Technical Literature Ref: _____ ☒ 3/ In-house Ref: _____	☒ 18/ Light microscope ☒ 10/ Electron microscope ☒ 5/ Other (Describe) _____ Ref: _____	☒ 9/ Manufacturer ☒ 3/ Technical Literature Ref: _____ ☒ 5/ In-house Ref: _____
6. What sizing diameter or parameter is measured?	☒ 4/ Aerodynamic ☒ 1/ Other (Describe) _____	☒ 5/ Feret's ☒ 9/ Equal Area ☒ 2/ Projected Area ☒ 7/ Other (Describe) _____	☒ 16/ Aerodynamic ☒ 2/ Other (Describe) _____
Comments: _____	_____	_____	_____

II. DATA HANDLING AND REPORTING OF RESULTS

A. If you use aerosol sampling methods which do not measure aerodynamic diameters, then:

1. Which of the following corrections do you use to convert the measured parameter to the aerodynamic diameter?

☒ 24 None ☒ 4 Density ☒ 0 Refractive Index ☒ 0 Filter Burial ☒ 3 Shape

☒ 4 Other (Describe) _____

2. How are these corrections applied? _____

B. Do you assume that the aerosols you sample fit any particular size distribution? ☒ 20 NO ☒ 15 YES, Log-Normal

☒ 6 YES, Other (Describe) _____

C. How many of the following statistics do you use to characterize aerosol concentrations?

☒ 31 Gross activity (or gross mass) per unit volume of air sampled.

☒ 12 Respirable activity (or respirable mass) per unit volume of air sampled.

Aerosol size parameters, including: ☒ 6 Mass median diameter ☒ 7 Mass median aerodynamic diameter

☒ 4 Activity median diameter ☒ 8 Count median diameter ☒ 2 Activity median aerodynamic diameter

☒ 8 Geometric standard deviation ☒ 1 Other (Describe) _____

☒ 4 Other statistic (Describe) _____

III. INFORMATION TO BE USED IN AN AEROSOL SAMPLING MANUAL

A. Do you have any data relating "respirable" to "gross" airborne concentrations, for specific operations, which could be released on an anonymous basis? ☒ 2 YES ☒ 36 NO Comments: _____

B. Would it be possible for the author of the proposed "Manual of Recommended Practice for Aerosol Sampling and Evaluation" to visit your facility during November or December 1974 and discuss your aerosol sampling equipment and techniques?

☒ 5 NO

☒ 32 YES, contact

Name: _____

Address: _____

Title: _____

Phone: _____

C. Which of the following aerosol sampler types do you use?

☒ 25 Personal sampler

☒ 21 Breathing zone samplers

☒ 32 Stack samplers

☒ 13 Emergency or indicating

☒ 33 Area samplers (delayed analysis)

☒ 23 Continuous air monitors (instant read-out)

D. Sampling Capabilities

1. With the devices and methods available to you, what are your expected delay times between receipt of the report of an incident requiring aerosol sampling, collection of the sample, and completion of the analysis?

35 (See Tables I and II)

2. What effect do you feel these delays have upon your control?

27 (See Tables I and II)

IV. Are there any comments, recommendations, criticisms, or special problem areas that you would like to include in this survey or in the proposed "Manual of Recommended Practice for Aerosol Sampling and Evaluation"?

11 (See Table III)

TABLE I
QUESTIONNAIRE RESULTS

	<u>No.</u>	<u>Replies (%)</u>
Facilities contacted	53	--
Facilities replying	37	100
Facilities using aerosol samplers	32	86
Corrections applied to sample data		
• None	18	49
• Particle density	2	5
• Refractive index	0	0
• Filter burial loss	0	0
• Shape factor	2	5
Aerosol size distribution assumed		
• None	18	49
• Log-normal	8	22
• Other	5	14
Type of sample taken		
• Total dust	29	78
• "Respirable dust"	7	19
• Size analysis	22	59
Aerosol sample statistics determined		
• Mass median diameter	4	11
• MMAD	4	11
• Count median diameter	6	16
• Activity median diameter	2	5
• AMAD	0	0
• Geometric standard deviation	6	16
Type of sampling performed		
• Personal	19	51
• Breathing zone	16	43
• Stack or duct	29	78
• Emergency or indicating	10	27
• Area (delayed analysis)	27	73
• Continuous (instant readout)	19	51
Time required for receiving report of incident, collection of sample(s), and completion of analysis		
• 0 - 60 min	7	19
• 1 - 8 h	9	24
• 1 - 2 days	8	22
• 1 - 5 days	3	8
• More than 5 days	1	2
Effect of these delays on control		
• Little or no effect	20	54
• Delays reporting	2	5
• Control more conservative than otherwise	2	5
• Adverse effect	1	2

TABLE II
QUESTIONNAIRE RESULTS FOR SIZE SELECTIVE SAMPLING

	<u>Two-Stage Samplers</u>		<u>Microscopic Size Analysis</u>		<u>Size Fractionating Samplers</u>	
	<u>No.</u>	<u>% of Replies</u>	<u>No.</u>	<u>% of Replies</u>	<u>No.</u>	<u>% of Replies</u>
Portion of all samples	7	100	15	100	12	100
• Special problems only	0	0	2	13	2	17
• 0 - 10%	6	86	8	53	6	50
• 11 - 25%	0	0	2	13	1	8
• 26 - 50%	0	0	0	0	0	0
• 51 - 100%	1	14	3	20	3	25
Reasons for sampling						
• Exposure documentation	4	57	14	93	10	83
• Health risk evaluation	6	86	15	100	12	100
• Investigate complaints	4	57	11	73	6	50
• Source identification	5	71	9	60	9	75
• Respirator selection	6	86	10	67	8	67
• Compliance with regulations	6	86	13	87	10	83
• Evaluate engineering controls	6	86	15	100	11	92
Radioactive particle sampling						
• Alpha	1	14	3	20	3	25
• Beta	1	14	0	0	4	33
• Gamma	1	14	0	0	3	25
Nonradioactive aerosol sampling						
• Free silica	2	29	3	20	0	0
• Beryllium	2	29	1	7	0	0
• Asbestos	0	0	6	40	0	0
• Heavy metals	2	29	1	7	1	8
Areas sampled						
• Personal samplers	6	86	12	80	8	67
• Breathing zone	4	57	10	67	6	50
• Stacks and ducts	7	100	13	87	11	92
• Emergency or indicating	1	14	4	27	5	42
• Area (delayed analysis)	6	86	11	73	10	83
• Continuous (instant readout)	3	43	5	33	7	58
Types of samplers used						
• Cyclone	0	0	0	0	0	0
• Elutriator	0	0	0	0	0	0
• Annular impactor	1	14	0	0	0	0
• Impinger	0	0	15	100	0	0
• Filter	0	0	15	100	0	0
• Electrostatic precipitator	0	0	1	7	0	0
• Cascade impactor	0	0	0	0	9	75
• Light scatter instruments	0	0	0	0	4	33
Type of sampler calibration used						
• Manufacturer's	3	43	0	0	9	75
• Technical literature	2	29	0	0	2	17
• In-house	2	29	15	100	1	8
• Light microscope	0	0	15	100	0	0
• Electron microscope	0	0	8	53	0	0
• Autoradiography	0	0	1	7	0	0
Corrections applied to data						
• None	4	57	8	53	5	42
• Particle density	1	14	2	13	0	0
• Index of refraction	0	0	0	0	0	0
• Filter burial loss	0	0	0	0	0	0
• Shape factors	1	14	1	7	1	8

TABLE II (cont)

	<u>Two-Stage Samplers</u>		<u>Microscopic Size Analysis</u>		<u>Size Fractionating Samplers</u>	
	<u>No.</u>	<u>% of Replies</u>	<u>No.</u>	<u>% of Replies</u>	<u>No.</u>	<u>% of Replies</u>
Particle distribution assumed						
• None	2	29	8	53	3	25
• Log-normal	4	57	6	40	7	58
• Parabolic	1	14	1	7	1	8
Size parameters measured						
• Aerodynamic diameter	2	29	0	0	11	92
• Feret's diameter	0	0	4	27	0	0
• Equal area diameter	0	0	7	47	0	0
• Projected area diameter	0	0	1	7	0	0
• Fiber length	0	0	3	20	0	0
• Fiber diameter	0	0	1	7	0	0
• Count of fibers > 5- μ m	0	0	2	13	0	0
Sample statistics calculated						
• Mass median diameter	1	14	3	20	2	17
• MMAD	1	14	2	13	4	33
• Activity median diameter	0	0	2	13	1	8
• Count median diameter	2	29	6	40	3	25
• AMAD	0	0	0	0	0	0
• Geometric standard deviation	3	43	6	40	5	42
• Percent respirable	1	14	1	7	1	8
Time required for receiving report of incident, collection of sample(n), and completion of analysis						
• 0 - 60 min	1	14	1	7	1	8
• 1 - 8 h	2	29	5	33	5	42
• 1 - 2 days	2	29	4	27	3	25
• 3 - 5 days	1	14	1	7	0	0
• More than 5 days	1	14	1	7	1	8
Effect these delays have on control						
• Little or no effect	3	43	8	53	7	58
• Delays reporting	0	0	0	0	2	17
• Control more conservative than otherwise	1	14	1	7	1	8
• Adverse effect	0	0	0	0	0	0

TABLE III

SUGGESTIONS AND COMMENTS

No comments were submitted by 26 of the 37 facilities replying.

The following comments were made by the remaining 11 facilities:

1. Aerosol sampling for exposure estimation is not practical at a plutonium facility.
2. A need exists for
 - A continuous alpha monitor insensitive to radon and thoron daughters.
 - Definition in simple terms of the aerosol size parameters.
3. Please discuss the following topics in the manual:
 - Oil mist sampling.
 - Choice of sample flow rates.
 - When to reduce or stop sampling.
 - When respirators should be used.
 - The use of continuous air monitors.
 - Preparation of samples for electron microscopy.
 - The importance of long term averages (> 6 months).
 - Bio-hazard sampling (dander, pollen, spores, etc.).
 - Size distribution of single source aerosols.
 - When particle size analysis should be done, and when it should not.
 - Statistical problems of sampling at the low MPCs of the heavy nuclides.
 - Collection of particles without an inherent size selection during sampling.
 - The fact that equal emphasis should be placed on collection, detection, and analysis.