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Aerosol monitoring during work inside the “object shelter”: Analysis of dispersion and concentration for different work types

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Abstract

Results of aerosol monitoring during work inside the object shelter (OS) are presented. Taking into account the fact that dispersion of the aerosol is one of the main factors affecting internal dose [Annals of the ICRP, ICRP Publication 66, Human Respiratory Tract Model for Radiological Protection, Pergamon Press, 1993], principal task of the investigation was the determination of the aerodynamic diameter (AD) distribution of the radioactive aerosol. Special attention was paid to transuranium elements' content in the aerosol since they are the major dose-producing radionuclides for the OS conditions. At present, work on stabilization of unstable constructions of the OS is in the active stage. Most of the work inside the OS leads to increased generation of radioactive aerosols. This work is carried out in the highly contaminated premises of the OS, where radioactive situation has been formed during the accident. Present work contains earliest results of the aerosol monitoring program for the period from September 2005 untill February 2006. Data obtained shows that for most types of work, radionuclides mainly located in the coarse aerosol fraction, activity median aerodynamic diameter (AMAD) range 8–12 μm. Work on the program continues at present time (actual data accumulation and analysis). Further widening of the program with the goal of type of material determination is described.

Keywords: “Object shelter”; Aerosol; Monitoring; Particle size distribution

1. Introduction

The main goal of the present work was to develop an airborne radioactivity monitoring program and obtain results on particle size distribution, concentration, and radionuclide composition directly in the breathing zone of the personnel during work inside the object shelter.

A special program of monitoring was developed. This program included four major directions:

i. Preparation and organization (permissions, instructions, manuals and order of performing of operations);
ii. Quality assurance program (marking, transportation, storage and management of media, calibration and deactivation of the equipment);
iii. Experimental part (air sampling procedure including supervision and monitoring of the procedure);
iv. Radiometric measurements (total activity of alpha- and beta-emitters, ^{137}Cs content, and radiochemical separation of $^{239+240}Pu$ and ^{241}Am).

After analysis of planned work inside the object shelter, tasks were divided into five major groups. Each group was assigned a corresponding classifier characterizing the work. A description of work and classifier is given in Table 1.

In fact, all radiationally dangerous jobs with the increased probability of radioactive aerosols generation were covered by the program.

2. Equipment

Six- and eight-stage models (296 and 298, correspondingly) of Marple personal impactors 290 Series were used to collect aerosol samples. “Gil Air-5” and “Gilian 3500” were used as air pumps during the sampling procedures. Flow rate was fixed at manual recommended level at 2 lpm [1]. The cut-off levels of impactor cascades are given in Table 2.

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Table 1
Description of works and appropriate classifiers

Description of the work	Type
Electric welding	1
Assembling work, clearing of work area (NO electric welding or abrasive cutting)	2
Work place preparation	3
Drilling, boring, battering	4
Abrasive cutting of metal	5

Table 2
Marple 290 series impactor cut-off levels (μm) for sampling rate 2 lpm

Cascade	AD (μm)
F	0
8	0.52
7	0.93
6	1.55
5	3.5
4	6
3	9.8
2[a]	14.8
1[a]	21.3

[a] For impactor model 298 only.

To calibrate the pumps and to set the required flow rate, two “Gilian” calibrators “Gilibrator-2” with heads “Gilian” (bubble generator) operating on soap solution were used. Calibration procedures were implemented before each sampling.

For capture of the aerosol particles which passed through cascades and final filter glass fiber paper SEC-290-GF type was used. Special air sample “passport” was developed to keep the data integrity and sample technical characteristics. The passport was filled in after the sampling and contained all necessary information about the individuals, work performed, sampling conditions and characteristics.

3. Results and discussion

Results to date are preliminary. At the present time, work on the program continues, including accumulating and improving the statistics and reliability of the results. According to the developed program, for the period from September 2005 till February 2006 more than 100 impactor measurements were carried out. All air samples obtained during the monitoring underwent measurement of total activity of alpha- and beta-emitters, and certain samples were selected for further radiometric analysis of ^{137}Cs content and radiochemical separation of $^{239+240}$Pu, ^{241}Am. The selection for further radiometric analysis was based on the reliable activity detection from low-level alpha- beta-counter. Data on aerosol distribution, radionuclide composition and concentrations of the radioactive aerosols during the works inside the OS was obtained. The data on dispersion of aerosol was analysed by number of standard methods described in [3–5].

Analysis of ^{137}Cs distribution for work types 2–5 shows that usually ^{137}Cs is contained in coarse aerosol fraction. In most cases ^{137}Cs content was detected on particles with AD of 3.5 μm and higher, while in number of cases ^{137}Cs content was detected in the whole AD range. Still contribution of the fraction with AD 3.5 μm and lower into total activity of ^{137}Cs did not exceed 25%. Experimental results mainly fit log-normal distribution well. ^{137}Cs activity can be described by log-normal distribution with activity median aerodynamic diameter (AMAD) within

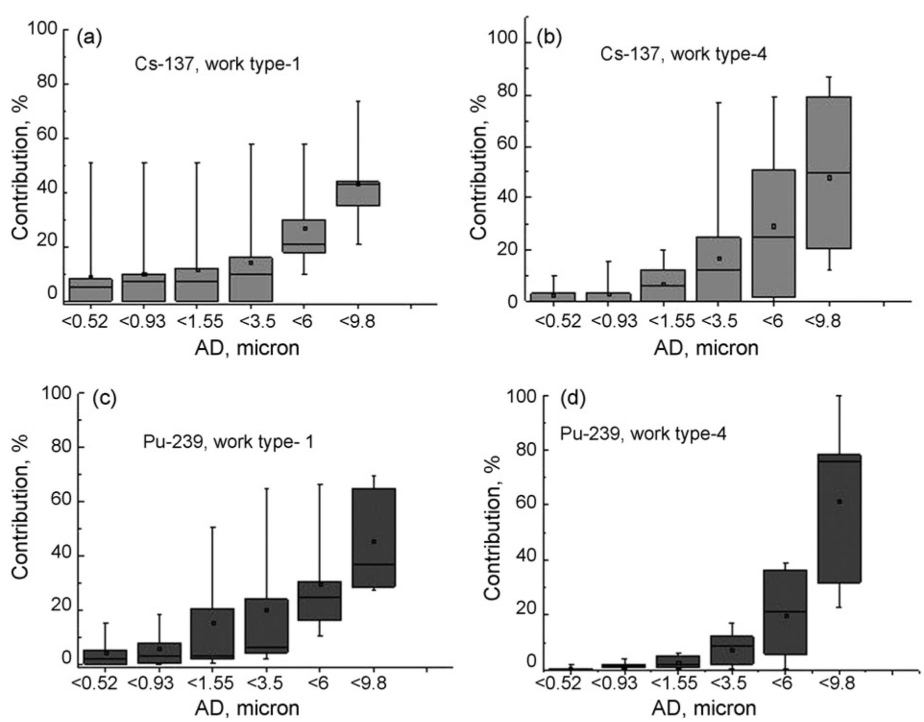

Fig. 1. Generalized cumulative distribution of radionuclides on AD for different work types: (a and b) ^{137}Cs, work types 1 and 4 correspondingly; (c and d) $^{239+240}$Pu, work types 1 and 4 correspondingly: “╧ , ╤ , □,—” are the min., max., mean and median value of the data range correspondingly.

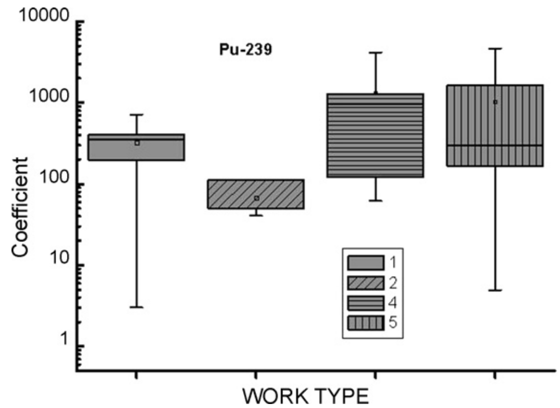

Fig. 2. Concentration increase coefficient for different work types. Radionuclide: $^{239+240}$Pu, workplace: room # # 635/3, 553/5, marks: +16, +24, +32, number of measurements—22.

6–12 μm, and geometric standard deviation (σ_g) in the range of 1.8–3.2.

At the same time work type 1 (work with electric welding) is of a special interest. Data on dispersion of ^{137}Cs for this type of work vary in very wide range. But it is determined that Cs distribution for this work type cannot be described as single-mode log-normal distribution because of a significant (sometimes up to 30%) contribution of the submicron component (final filter with AD range of 0–0.5 μm). This fact can be explained for this work type by high-temperature sublimation of Cs.

Unlike ^{137}Cs, $^{239+240}$Pu distribution for any type of work 1–5 has no such tendency and can be described by log-normal distribution with AMAD range 8–12 μm and σ_g 1.6–4.8, depending on work type. Generalized cumulative distribution on AD of $^{239+240}$Pu and ^{137}Cs for work types 1 and 4 is presented in Fig. 1.

Investigation of increases in radioactive aerosol concentration ("concentration increase coefficient" during work implementation) was carried out for the same work types mentioned in Table 1. A "concentration increase coefficient" is defines as the ratio of aerosol concentration during work to the concentration before work. Fig. 2 presents dependence of concentration increase coefficient of $^{239+240}$Pu on work type for workplace in rooms 635/3, 553/3. The background concentration of $^{239+240}$Pu (concentration before the work) in these rooms is stable in the range 6.6×10^{-04} to 8.1×10^{-04} Bq m^{-3}.

Results obtained allow one to determine that work of fourth and fifth types are to the most dangerous from the point of view of radioactive aerosol concentrations. High coefficient values, with maximum of 4500, can be explained by type of work. Thus, for work type 4, most of the work was carried out with highly contaminated concrete that was poured in 1986 (during the liquidation of the accident). Work of fifth type was mainly carried out with the goal of removing/dismantling metal constructions highly contaminated during the accident.

4. Conclusion

Generalized results on particle size distribution, radionuclide composition, and concentrations of radioactive aerosols as a function of the type of work are obtained and analysed.

For work without usage of electric welding, radionuclides are mainly found in the coarse aerosol fraction. For aerosols containing $^{239+240}$Pu observed data can be described by lognormal distribution with AMAD in the range of 8–12 μm and σ_g 1.6–4.8.

On the basis of experimental data the most radiologically dangerous types of work inside the OS from the stand point of increasing concentration of radioactive aerosol are determined to be abrasive cutting of metal and boring/battering of concrete.

Results of the investigations are used for planning and optimization of radiation protection.

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