RADIATION PROTECTION OF PERSONNEL IN DECONTAMINATION OF HOT LABORATORIES

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1. Introduction

In the Tokai Research Establishment of JAERI, there are two hot laboratories for post-irradiation examinations of nuclear fuels and materials. One is used for monitoring Magnox fuels from the gas cooled reactor (Calder Hall Type Reactor) and irradiated materials, and the other for post-irradiation examinations of nuclear fuels from light water reactor power plants.

In cutting the fuels or polishing the samples for metallurgical examination, radioactive particulates containing fission products are dispersed in the cell, and surfaces of the equipment, floor and walls are radioactively contaminated. In the respective cells, at the times of periodical maintenance of the in-cell equipment and repair of defective machines, decontamination is made for minimizing personnel exposure doses.

This paper describes the radiation monitoring and protection in cell decontamination, and discusses the data obtained in radiation monitoring.

2. Radiation Monitoring

Decontamination in the cells is usually conducted in the following steps: 1) removal, storage or disposal of irradiated fuel or material, cuttings etc. by remote operation, 2) wiping off cuttings etc. by manipulator with rags, 3) measurements of the exposure rate and surface contamination density in the cell with a manipulator, 4) repeated decontamination by hands with personnel entry into the cell, and 5) repeated measurements of the exposure rate and surface contamination density.

Low levels of the exposure rate and surface contamination density are set for decontamination operation so that the personnel can conduct maintenance or repair work in light protective outfit and their exposure doses may be as low as reasonably possible. In many cases, about 2×10^{-5} μCi/cm^2 is set for the surface contamination density and a few mR/h for the exposure rate, except for hollows and crevices of the equipment and gaps between the floor and machines which are hard to decontaminate.

In decontamination, the procedure is first planned and then the methods and the reduction levels of exposure rate and surface contamination are determined. Prior to the operation, a radiation work permit is issued, and the techniques of radiation monitoring and personnel protection including the outfit and the preventive measures for spread of contaminants are determined.

During the decontamination work with personnel entry into the cell, the radioactive concentration and any abnormality are constantly monitored in the cell, isolation room and service area. In the course of decontamination, the exposure rate and surface contamination density are measured in the cell at suitable stages of operation, and the decontamination and radioactivity measurement are

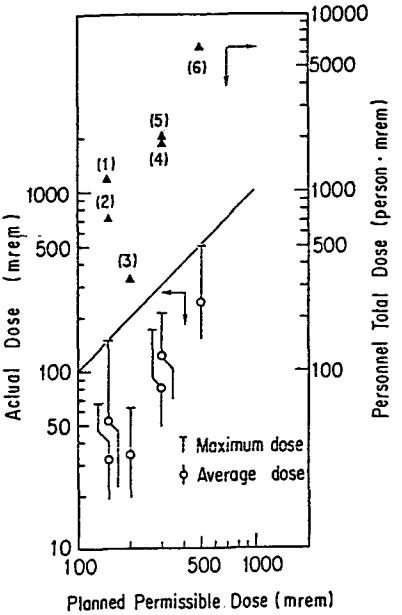

Fig.1 Individual and total dose of personnel vs. planned permissible dose in cell decontamination
Decontam. operation: (1) 24 persons x12 days, (2) 23x12, (3) 14x20, (4) 24x18, (5) 17x30, (6) 26x80.

repeated until the planned reduction levels are attained.

Personnel wear personal dosimeters, and their exposure doses are controlled by limiting the entry time not to exceed the planned permissible dose. Figure 1 shows individual and total dose of personnel vs. the planned permissible dose in recent decontamination works. As seen in the figure, nobody received the doses more than the planned permissible leves, and the ratio of the actual dose to the planned permissible level was between 1 and 1/2. The ratio of the maximum to the average dose is nearly between 2 and 3.

The protection for inhalation was made according to the guide in Table 1. Internal contamination was not detected in the decontamination personnel by the survey of the noses or the whole body counting after work. This means that the protection method was suitable.

3. Discussion of Radiation Monitoring Data

Decontamination Factor

When irradiated fuel or material was handled in the cell, the exposure rate was very high from hundreds R/h to tens of thousands R/h. After removal from the cell, including the cutting etc. and then the suction of cuttings with a vacuum cleaner or wiping them off by manipulator with rags, the exposure rate and surface contamination decreased to about 500 mR/h and $10^{-2}\mu Ci/cm^2$, respectively. Subsequently, the decontamination was made by hands with mops until the planned reduction levels were attained. As shown in Table 2, the exposure rate decreased only by one order at most but the surface contamination decreased by 2 ~ 3 orders. In cell decontamination with personnel entry, the decontamination factor, F, for exposure rate and surface

Table 1 Guide for respiratory protective devices to be used in JAERI

air concentration	surface contamination	respiratory protective device
$< (MPC)_a^{40}$	α: $< 10^{-4}$ μCi/cm^2 β: $< 10^{-3}$	half mask (if required)
$1\ (MPC)_a^{40} \sim 10(MPC)_a^{40}$	α: $10^{-4} \sim 10^{-3}$ β: $10^{-3} \sim 10^{-2}$	half mask or full-face mask
$10(MPC)_a^{40} \sim 100(MPC)_a^{40}$	α: $10^{-3} \sim 10^{-2}$ β: $10^{-2} \sim 10^{-1}$	full-face mask, SCBA*, SAM* or PAPR*
$100(MPC)_a^{40} <$	α: $10^{-2} <$ β: $10^{-1} <$	PAPR* or SAS*

* SCBA: self-contained breathing apparatus
PAPR: powered air-purifying respirator (suit)
SAM: supplied-air mask, SAS: supplied-air suit

Table 2 Decontamination factors for cell decontamination with personnel entry

item facility	Hot Lab.A	Hot Lab.B
dose rate		
pre-decontam., mR/h	70 ~ 1500	10 ~ 500
post-decontam., mR/h	10 ~ 120	1 ~ 50
surface contam. level		
pre-decontam., $\mu Ci/cm^2$	$2x10^{-3} \sim 2x10^{-2}$	$2x10^{-4} \sim 2x10^{-3}$
post-decontam., $\mu Ci/cm^2$	$2x10^{-6} \sim 1x10^{-5}$	$1x10^{-6} \sim 3x10^{-5}$
decontam. factor		
for dose rate	10 ~ 20	5 ~ 10
for surface contam.	2000 ~ 10000	100 ~ 200

contamination were 10 and 100~1000, respectively. The nuclides of contaminants were fission products of Cs-137, Sr-90, Y-90, Ru-106, Rh-106, Ce-144, Pr-144, Zr-95, Nb-95, Sb-125, etc., activated products of Mn-56, Co-60, etc. as ß-emitters, and transuranic elements of Pu-238, Pu-239, Pu-240, Am-241, Cm-242, Cm-244 etc. as α-emitters. The nuclide Co-60 originated in cutting of the fuel coating materials. In the cell where the coating materials were cut, Co-60 accounted for about 90% of the total radioactivity.

Resuspension Factor

Due to decontamination operation and to the action of ventilation air turbulence, the contaminant particles deposited on the floor and machines surfaces are exfoliated and blown up into the air, leading to the air contamination. To know the extent of this dispersion is very useful for estimating preliminarily the extent of air contamination and for considering the personnel protection for inhalation.

Resuspension factors of particles as an indication of the air contamination, i.e. the ratio of the air concentration to the surface contamination density, are shown in Fig. 2 in frequency distribution, where the values were calculated for surface contamination densities over $10^{-4}\mu Ci/cm^2$ inclusive. As seen in the figure, the resuspension factors in decontamination works ranged between $10^{-8}cm^{-1}$ and $10^{-4}cm^{-1}$ the geometric mean was $K_g = 1x10^{-6}\ cm^{-1}$ and the geometric standard deviation was $\sigma_g = 8$.

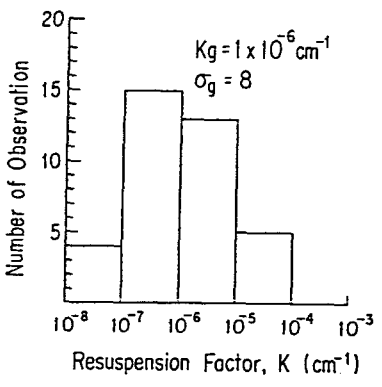

Fig.2 Frequency distribution of resuspension factors obtained in decontamination work

Particles deposited in the cell were produced in cutting or polishing the irradiated fuel or material. The particle size distributions measured by a cascade impactor are shown in Table 3. The activity median aerodynamic diameters were AMAD = 6 μm ~ 17 μm and the standard deviations were $\sigma_g = 1.2 \sim 2.7$; these AMADs are considerably large in the respect of possibility of their inhalation. These values are nearly the same as those (AMAD = 2.5 μm ~ 11 μm, σ_g = 1.7 ~ 3.2) previously measured by Ikezawa et al. [1] in one of the hot laboratories.

The resuspension factors of deposited particles in cell decontamination are fairly large, by four orders or more, larger than the value

Table 3 Size distribution of radioactive particles blown up into air during cell decontamination measured by cascade impactor

cell No.		1	2	4	5	6
particle size distribution	AMAD(μm)	16	6	17	8	13
	σ_g	2.4	2.7	1.3	1.9	2.2

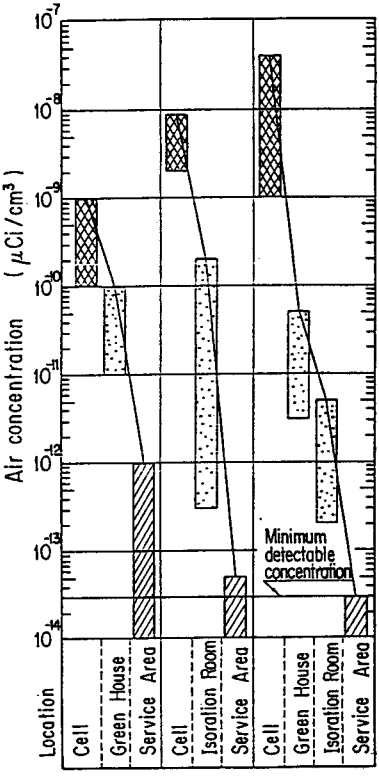

Fig.3 Radioactive air concentration in cell, green house, isolation room and service area during cell decontamination

of $K = 2 \times 10^{-8}$ cm^{-1}, which was obtained by Dunster [2] and which has been widely used as the base for the limits of surface contamination density.

Prevention of Contamination Spread with an Isolation Room

An isolation room is set up behind the cell to prevent the spread of contaminants during decontamination, to bring in equipment into the cell, and to take out the contaminated equipment from the cell or temporarily store it and also intermidiate-level solid wastes.

In Fig. 3 are shown radioactive air concentrations in the cell, the isolation room (or a green house temporarily built) and the service area, which were obtained by air monitoring during decontamination. As seen in the figure, the air concentrations in the isolation room or the green house decreased to 1/10 ～ 1/100 of those in the cell but not to nil. This is ascribed to the back door of cell being entirely open during decontamination. However, this room decreased extremely the leakage of contaminants to the service area. When a green house was set up within the isolation room, the leakage of contaminants to the service area was reduced to almost zero; and the air concentration there was undetectable.

References

(1) Y. Ikezawa, T. Okamoto, A. Yabe: Proceedings of the 5th Congress of the International Radiation Protection Society, p. 495-498, Jerusalem (1980)
(2) H.J. Dunster: Health Phys., 8, 353-356 (1962)