SYSTEMATICS OF GAMMA-RAY ENERGY SPECTRA FOR CLASSIFICATION OF WORKPLACES AROUND A NUCLEAR FACILITY

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1. INTRODUCTION

Radiation dosimetry in workplaces has been carried out both for assurance of the doses complying with the acceptable values and for improvement of protection methods to minimize detriments of the exposed population. This means that it is very impotant not only to determine dosimetric quantities in workplaces but also to know features of radiation fields because information for radiation protection can be often derived from the radiometric quantities.

Classification of workplaces based on the fearure of gamma-ray energy spectra is one of practical ways to realize radiation protection being taken into consideration of the radiometric quantities. Furthermore, demarcation of workplaces based on these radiometric quantities may be effective for improvement of radiation protection practice such as estimation of radiation doses, designing of radiation shields and other activities.

From these points of view, gamma-ray energy spectra have been determined in various workplaces in nuclear facilities, and systematics of gamma-ray fields were tried for classification of workplaces on the basis of the feature appeared in health physical quantities such as effective dose equivalents and reponses of dosemeters.

2. EXPERIMENTAL

2-1 Measuring System and Measurements

Gamma-ray energy spectra in some workplaces of the Research Reactor Institute of Kyoto University were determined by the scintillation spectrometer with a 7.6 cm diameter and 7.6 cm long cylindrical NaI(Tl) crystal covered with a 2 mm thick bakelite cover. The scintillation detector was supported with a tripod about 1.2 m high. Data from the detector were recorded in the multi-channel pulse-height analyzer. Pulse-height distributions were analyzed into gamma-ray energy spectra with an unfolding technique using mini-computer system.

Workplaces chosen for measurements of gamma-rays were (1) TL (laboratory for physical, chemical and biological treatment of low level radioactive materials), (2) HL(laboratory chemical processing of high level radioactive materials) and (3) RR(reactor building containes the light water cooled reactor and related experimental equipments). Measurements were carried out at 19 places in these laboratories.

2-2 Determination of Dosimetric Quantities

Dosimetric quantities discussed here were exposures(Ex), effective dose equivalents(EDE) and ambient dose equivalents(ADE). Ex could be determined after well-known formula using gamma-ray energy spectra and energy absorption coefficients of air. EDE and ADE could be derived from the exposure multiplied by the Ex to EDE and ADE conversion factors, respectively/1,2/. Responses of a Geiger-Muller serveymeter and a filmbadge dosimeter were calculated using energy dependences of these counter and dosimeter sensitivities/3,4/.

3. RESULTS AND DISCUSSION

3-1 Gamma-ray Energy Spectra

Examples of gamma-ray energy spectra obtained in TL and HL are illustrated in Fig.1 and Fig.2. Broken histograms in these figures show the energy spectra due to natural radionuclide in the laboratory. It is evident from these results that the artificially

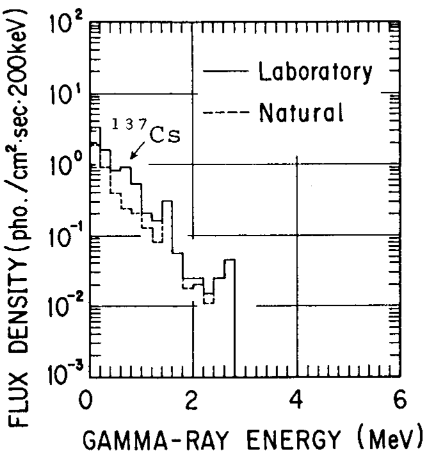

Fig.1 Gamma-ray energy spectra around chemical laboratories.

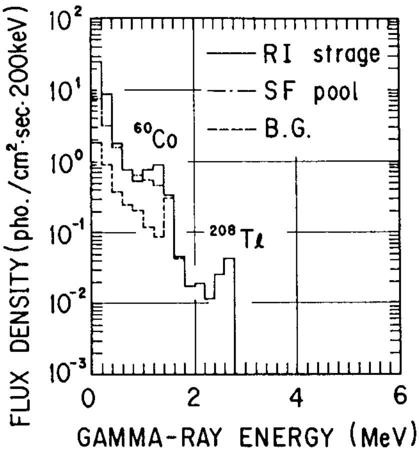

Fig.2 Gamma-ray energy spectra around RI/SF strage facilities.

increased gamma-rays, which are attributable to radionuclides such as ^{60}Co and ^{137}Cs, are observed below 1.4 MeV and that intense low energy photons are observed near the strage facility for radioactive isotopes or spent fuels of the reactor. On the other hand, as illustrated in Fig.3, higher energy gamma-rays are observed aound a neutron source strage facility. This seems to be caused by an Am-Be neutron source which emits about 4.4 MeV gamma-rays as well as netrons after nuclear reaction of $^{9}Be(\alpha,n)^{12}C$.

Examples of gamma-ray energy spectra observed in the reactor building are illustrated in Fig.4. Solid histogram shows the energy spectrum obtained during reactor operation at the power of 5 MW and broken one shows a background gamma-ray energy spectrum. It is apparent from these histograms that gamma-rays in the reactor building were mainly caused by neutron capture reactions of argon,

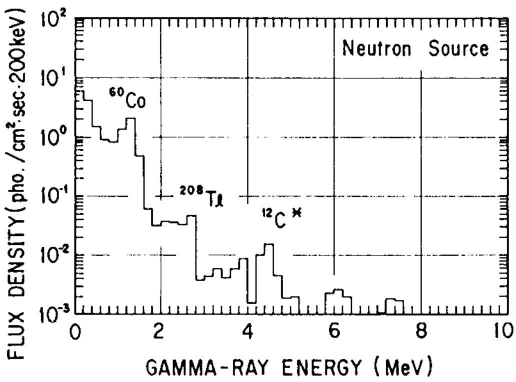

Fig.3 Gamma-ray energy spectrum around a neutron source strage facility.

hydrogen, iron and other nuclides, and that they distributed up to energy about 9.2 MeV. Gamma-ray energy spectra obtained at basement of the reactor building is illustrated in Fig 5. As shown by the solid histogram in Fig.5, gamma-rays from ^{16}N created by ^{16}O(n,p) reaction in the coolant circuit and from ^{41}Ar leaked from the reactor room of the building are clearly observed by the operation of the reactor.

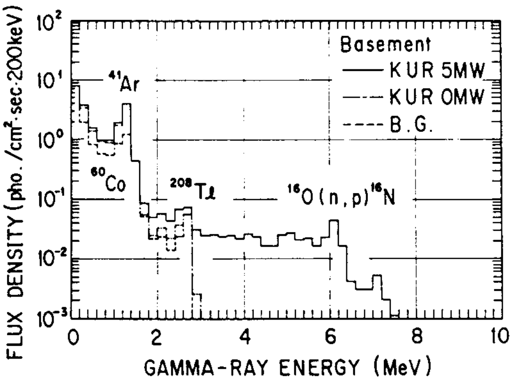

Fig.4 Gamma-ray energy spectra in workplaces around the KUR.

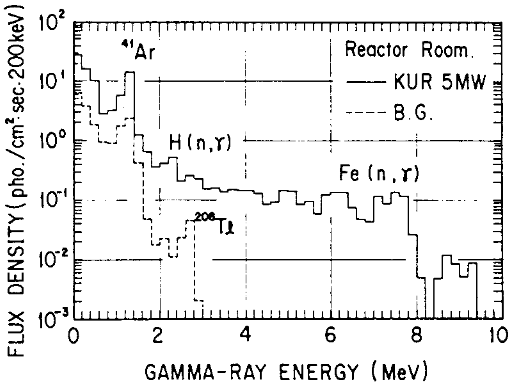

Fig.5 Gamma-ray energy spectra around coolant of the KUR.

3-2 Relation between dosimetric and radiometric quantities

Ex rates, EDE rates and ADE rates were determined on the basis of the energy spectra of workplaces and serveymeter responses or filmbadge readings were determined by accumulating exposures multiplied by the detector sensitivity. To discuss relations among these health physical quantities regardless of the total exposure rate, each dosimetric quantitie was divided by the Ex rate. The results are shown in Table 1. The number in each line was given by averaging over several results obtained at workplaces where gamma-

Table 1. Ratios of dosimetric quantities and dosimeter responses to exposure.

workplace	energy	EDE/Ex	ADE/Ex	film/Ex	GM/Ex
RI/SF strage	<0.4 MeV	0.90	1.14	0.44	1.34
chemi.res.labo.	<3 MeV	0.87	1.06	0.53	1.28
reactor room	>3 MeV	0.86	1.03	0.57	1.34

ray energy spectra showed similar characteristics. Typical workplaces and some features appeared in gamma-ray energy spectra are shown in the first and second column of the table. It is clear from the two dosimetric quantities in the table that the ratios shown in the first line is markedly defferent from the other ones and that smaller differences can be seen between ratios obtained in the medium and higher energy gamma-ray fields. Furthermore, it is to be noted that the ratios in the third and fourth columns become small with increasing maximum photon energy in the workplaces contrary to the feature appeared in the results in fifth and sixth columns. Though the difference of the minimum and maximum values in each column are within 30 %, it is very important to realize that low energy photons give larger Ex to EDE or ADE conversion factors and they can be shielded by a simpler protective way and that dosimetric quantities or detector responses show complicated charactors in higher energy gamma-ray fields. These two facts indicate that an application of a unique method is not appropriate to get reliable information for radiation protection This means that classification of workplaces based on the feature of the energy spectrum will be powerful for establishing reasonable methods for radiation protection.

4. CONCLUSIONS

It becomes clear from the investigation that gamma-ray fields can be classified into three groups: (1) low energy gamma-ray fields mainly composed by scattered photons, (2) medium energy gamma-ray fields formed by utilization of radioactive materials and (3) high energy gamma-ray fields due to neutron capture in mixed radiation fields. It is also quite possible that radiation protection practice will be reasonably improved by the demarcation of workplaces on the basis of these feature of gamma-ray fields.

References

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