VIII-II-1. Project Research

Project 12

PR12 Studies on Radiation Safety Control at Accelerator Facilities

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Objectives and Allotted Research Subjects

A Fixed-field Alternating-Gradient (FFAG) proton synchrotron (max energy 150 MeV, max mean current 1 nA) has been constructed next to the KUCA to study the technological development for the accelerator driven subcritical reactor (ADSR). The proton beam was led to the KUCA A-core to conduct the experiment of ADSR on March 4, 2009. On the other hand, the commissioning of a 30 MeV proton cyclotron was completed at the end of March, 2009, for the boron neutron capture therapy (BNCT). And other high energy accelerators are scheduled to conduct in the master plan at KURRI. In these situations, the radiation safety control at accelerator facilities is a key issue in the workplaces and environment. In this project study, seven research subjects were carried out in three facilities (B-core room of KUCA, the electron linear accelerator, and the Co-60 gamma irradiation facility) as substitutes related to the accelerators fields.

The allotted research subjects (ARS) are as follows:

ARS-1 (21P12-1): Estimation of the Initial Guess Spectrum for Estimation of Neutron Energy Spectra in the Vicinity of the Irradiation Facility of the BNCT.
(I. Urabe, *et al.*)

ARS-2 (21P12-2): Development of Passive Neutron Dosimeter with Good Energy Response.
(T. Iimoto, *et al.*)

ARS-3 (21P12-3): Accelerator Neutron Dosimetry Using Composite Proportional Counting Tube.
(M. Hashimoto, *et al.*)

ARS-4 (21P12-4): Production and Behavior of Tritium in Accelerator Laboratory.
(M. Ohta, *et al.*)

ARS-5 (21P12-5): Behavior of Colloidal Species Formed in the Cooling Water of Accelerator Facilities.
(K. Bessho, *et al.*)

ARS-6 (21P12-6): Influence of Radioactive Gas on Size Measurement of Radioactive Aerosol Particles by Diffusion Battery Method in Accelerator Facilities.
(Y. Oki, *et al.*)

ARS-7 (21P12-7): Influence of Collecting Substrates on Size Distribution Measurement of N-13 and Rn-progeny by Low Pressure Cascade Impactor in the Linac Facility.
(K. Yamasaki, *et al.*).

Main Results

ARS-1: Energy spectra of the leakage neutrons from the BNCT irradiation facility room were estimated at the place near around the facility and at the natural environment 100 m apart from the facility. It became clear that relatively high intensity neutrons of 1-10 MeV are observed near around the facility.

ARS-2: A passive personal neutron dosimeter consists usually a combination of CR-39 (Poly-Allyl diglicol carbonate) and 1 mm thickness polyethylene sheet. This dosimeter is hard to measure neutron energy. Many types of radiator such as polyethylene, Al, Fe and their combinations were examined in order to adjust energy response for neutron.

ARS-3: Neutron energy spectra were measured at rotary shield room and B-core room of KUCA using the composite proportional counting tube which was filled with ^{3}He-CH$_4$ mixed gas. High energy neutron was observed at B-core room larger than at rotary shield room.

ARS-4: The concentration of radioactive gaseous particles contained in exhaust gases from accelerator for BNCT was continuously measured. Some peaks of the concentration emerged within about 3 min after the operation of the accelerator.

ARS-5: Relatively high concentrations of Cu, Fe and Al were observed in the cooling water of LINAC. Especially at the down stream position, total metal concentrations were high and large particles were created. These results suggest that bremsstrahlung irradiation promotes not only corrosion of metal surfaces but generation and growth of colloidal metal species in water. On the other hand, creation of large colloidal Cu$_2$O was promoted by the high dose of Co-60 γ-ray irradiation.

ARS-6: The particles bearing ^{13}N which is the principal nuclide of electron linear accelerators coexist with a large amount of ^{13}N gaseous species. The coexisting gas may interfere in exact measurement of the size distribution of the radioactive particles. In this work, influence of adsorption of radioactive gas was shown in the measurement with a wire screen diffusion battery.

ARS-7: The influences of collecting substrates on the size distribution measurement of N-13 and Rn-progeny were examined using a low pressure cascade impactor in the Linac facility. It was shown that the use of a soft silicone rubber sheet as a collecting substrate might enlarge the geometrical standard deviation of N-13 aerosols.

採択課題番号 21P12　加速器施設における放射線安全管理に関する研究　プロジェクト
（京大・原子炉）　高橋千太郎

PR12-1 Estimation of the Initial Guess Spectrum for Estimation of Neutron Energy Spectra in the Vicinity of the Irradiation Facility of the BNCT

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INTRODUCTION : Neutron energy spectra have been needed to know propagation characteristics of neutron doses around medical facilities utilizing nuclear reaction. Determination of neutron energy spectra which would usually be practiced by iteration methods using some measured data and response matrix representing sensitivity of detectors has been needed an initial guess spectrum for analysis of neutron energy spectra at places of interest around nuclear facility. For estimation of initial guess spectrum for using analysis of the data measured with multi-moderating type He-3 neutron spectrometer neutron energy spectra around irradiation facility of the BNCT have been calculated using MCNP-5 calculation code.

METHOD: Neutron Energy spectra near around the irradiation facility room of the BNCT were calculated. The irradiation room was assumed to be surrounded with the walls which were 1.5 [m] in thickness. The detector 1 was placed on the wall outside the BNCT building and the detector 3 was placed on the wall in the control room of the neutron irradiation facility, and the detector 2 whose direction is parallel for the charged particle beam direction is placed on the wall outside the irradiation room. Neutron propagation to the natural environment was also calculated. Cross sectional view of the irradiation facility in the air which is used for calculation model for estimation of neutron propagation from the irradiation facility room to the natural environment is shown in Fig.1. The detector 4 is placed at 100 [m] from the irradiation facility.

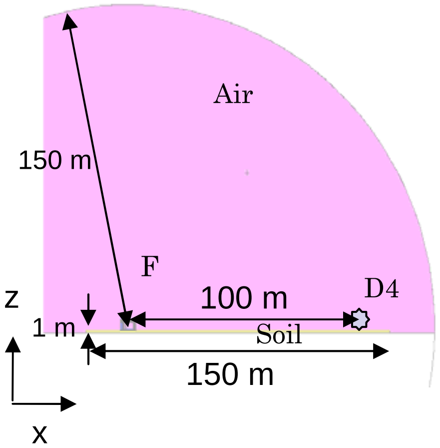

Fig. 1. Model used for calculation of neutron energy spectra in the natural environment. F and D4 are irradiation facility and a detection point, respectively.

Neutron energy spectra in the application document for permission of construction of the BNCT were used for source neutron energy spectra in the forward direction and that perpendicular to the beam line to the charged particles. Calculations were performed using the MCNP-5 code with the cross sectional data of the JENDL3.3.

RESULTS and DISCUSSION

Energy spectra of the leakage neutrons from the irradiation facility room to the places near around the facility and in the natural environment are shown in Figs.2 and 3, respectively. It became clear from these figures that relatively high intensity neutrons from 10^0[MeV]～10^1[MeV] are observed near around the irradiation facility and they are still observed at 100 [m] in the natural environment. Since the measured spectra depends on the feature of the initial guess spectrum these spectra will be useful to confirm the artificially modified neutron energy spectra in the working places as well as in the natural environment.

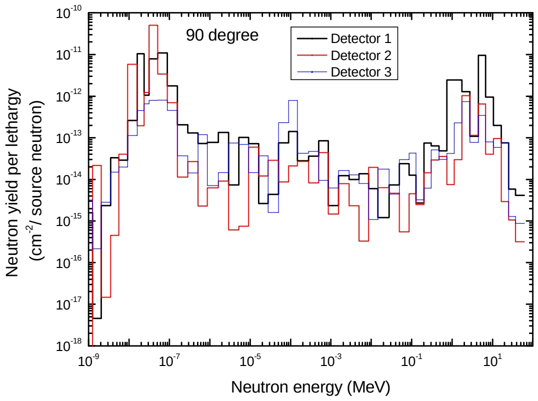

Fig. 2. Neutron energy spectra at detector 1, detector 2 and detector 3 positions around the irradiation room of the BNCT.

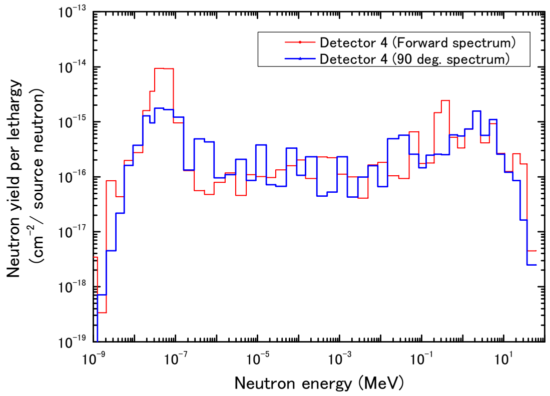

Fig. 3. Neutron energy spectra at the point 100 [m] away from the irradiation facility in the natural environment.

採択課題番号 21P12−1　　加速器施設における中性子線量計測・評価　　　プロジェクト
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（京大・原子炉）山崎敬三、八島　浩

PR12-2 Development of Passive Neutron Dosimeter with Good Energy Response

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INTRODUCTION: A passive personal neutron dosimeter consists usually a combination of CR-39 (Poly-Allyl digricol carbonate) and one millimeter thickness polyethylene sheet (PE1). It is hard to measure neutron energy using only CR-39 with PE1. This dosimeter could not follow changes on radiation weighting factor. [1] In order to adjust energy response for neutron, many types of radiator have been designed here and those energy responses have been checked.

EXPERIMENTS: This experiment was performed at LINAC facility at Research Reactor Institute, Kyoto University (KURRI). A photo-neutron target of Ta was used as an intense neutron source. The target was set without water tank. The KURRI linac was operated with an electron energy of 30 MeV and average current of 105 μA. CR-39 was set at the end of beam tube (12 m-length). Exposure time was one hour. Table 1 shows a combination of radiators to be exposed to neutron in this experiment (PE: polyethylene, Al: Aluminum, Fe: Iron, Pb: lead, no: nothing). Figure 1 shows experimental geometry of CR-39 with radiators. After neutron exposure, CR-39s were chemically etched for 3.0 h in a circulating bath of 6.25 mol/L NaOH solution at a temperature of 90±0.4℃. Figure 2 shows etch-pits of j-type radiator. Many etch-pits overlapped etch other as shown in Figure 2, therefore we counted these etch-pits by manual technique.

RESULTS: Figure 3 shows number of etch-pits for each radiator combination. Polyethylene layer works as a kind of degrader: energetic recoils produced in No.3 layer loss its energy in No.1 and No.2 polyethylene layer. Only metal radiator (type: f, i, l) shows more number of etch-pits than metal radiator with PE. Metal has more atomic density than polyethylene, therefore metal can emits more secondary radiation than polyethylene exposed to high energy neutrons.

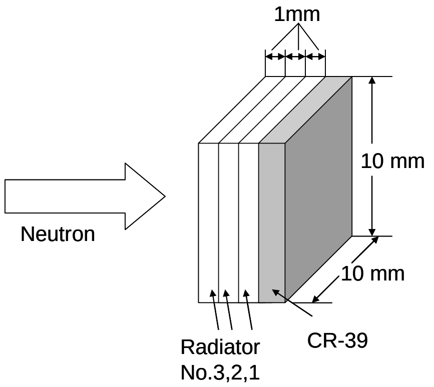

Fig. 1. Geometry of CR39 with radiators.

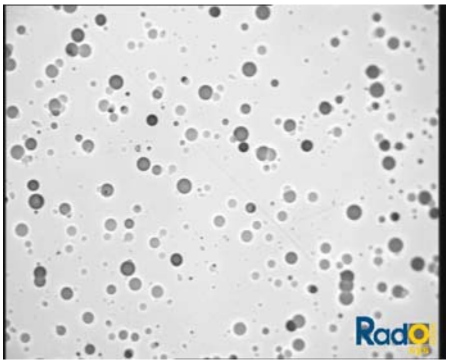

Fig. 2. j-type radiator's etch-pits.

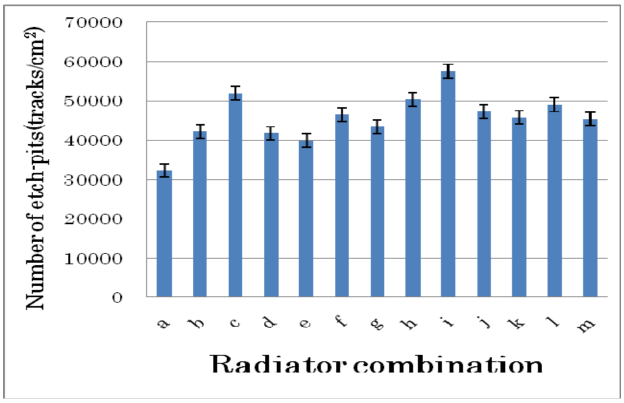

Fig. 3. Number of etch-pits of each radiator combinations.

REFERENCES:

[1] International Commission on Radiation Protection (2008) "Recommendations of the ICRP Publication 103" Ann. Of the ICRP, 37.

Table 1. Radiator combinations.

Radiator No	a	b	c	d	e	f	g	h	i	j	k	l	m
1	no	PE	PE	PE	PE	Al	PE	PE	Fe	PE	PE	Pb	PE
2	no	no	PE	PE	Al	no	Al	Fe	no	Fe	Pb	no	Pb
3	no	no	no	PE	no	no	PE	no	no	PE	no	no	PE

採択課題番号 21P12-2　エネルギーレスポンスの良好なパッシブ型中性子線量計の開発　　プロジェクト
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PR12-3 Accelerator Neutron Dosimetry Using Composite Proportional Counting Tube

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INTRODUCTION: The composite proportional counting tube which is filled with ^{3}He-CH_4 mixed-gas is developed. It has compound characteristics for neutron measurement. ^{3}He detects thermalized neutron while CH_4 is provided for relatively fast neutron detection. The output of each reaction can be distinguished with PHA analyzing because the scattered charged particle with fast neutron composes a continuous spectrum while the thermal neutron absorption composes a peaked spectrum. The ratio of each reaction reflects the neutron energy distribution. Furthermore, when the convex hull data treatment method is applied, the composite proportional counting tube can measure the neutron dose along with the neutron field characteristics [1]. The function of the convex hull of this detector with various fission neutron is calculated. It is confirmed that all the cases irradiated with various fission neutron fit with the convex hull. The characteristics of dose evaluation are also confirmed. The error of this detector for neutron dose evaluation is comparable with current neutron dosimeters. This detector has advantage in its weight and autonomy [2].

The dosimetry characteristics are experimentally confirmed with several reactors [2]. However, for the neutron dosimetry of accelerator-driven reactors, it is necessary to confirm about the adaptability of this method. It is because the neutron arise from the accelerator-driven reactors may consists of fission neutron and accelerator neutron. The convex hull may be different and the dosimetry characteristics might be revised.

In this year, reference data of the composite proportional counting tube measuring in KUCA is collected.

EXPERIMENTS: Measurements with the composite proportional counting tube were conducted in the stage next to the core B and in the rotary shield room with drive of core B. Neutron energy spectra of the measuring points are also measured using the Bonnar ball method.

RESULTS: The neutron spectra of each measured place are shown in Fig.1. The outputs of the composite proportional counting tube are collected. However, the output spectrum obtained at the core B room contains plenty of Schott noise because of the neutron incident in the amplifier. The Schott noise has normal distribution theoretically. It is cancelled with hypothetically normal distribution background signal. The outputs are processed and put into the convex hull of the detector. Fig. 2 shows the convex hull enlarged around the experimental results. The right hand plot of experimental result in KUCA shown in Fig.2 is the data measured in the core B room. Neutron energy is higher than another measurement point as shown in Fig.1, and the place in convex hull is closed up to the group of high energy group.

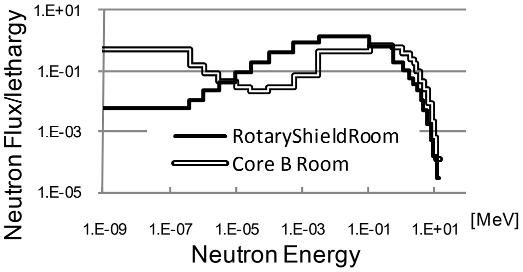

Fig. 1. Evaluated neutron spectra at measured places.

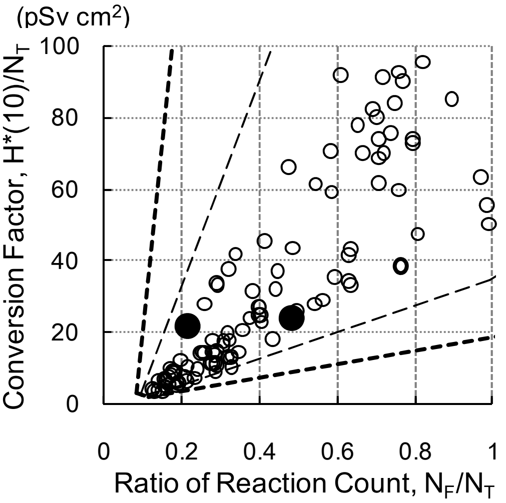

Fig. 2. Experimental results placed in the convex hull.

– – : Basal convex hull
----- :Contracted convex hull
● :Experimental results in KUCA
○ :Other Results(Experiment and calculation)

It is confirmed that the convex hull of the composite proportional counter for fission neutron is also functioned for the neutron field of which the source is the core B. These results are the basis of further evaluation of accelerator-driven reactor neutron dosimetry.

REFERENCES:

[1] M. Hashimoto *et al.*, Radiat. Prot. Dosimetry, **136(1)** (2009) 1-10.
[2] M. Hashimoto, Ph.D. Thesis, The University of Tokyo (2009).

採択課題番号 21P12-3　　複合型比例計数管による加速器中性子線量評価　　　　プロジェクト
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PR12-4 Production and Behavior of Tritium in Accelerator Laboratory

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INTRODUCTION

Radioactive particles are known to generate in the working field of accelerator. Then, the concentration of radioactive particles in the working field of fixed Field Alternating Gradient Accelerator (FFAG) is necessary to be measured before and after working FFAG. However, the concentration of gaseous radioactive particles exhausted from working FFAG in 2009 was too low to be measured as monitoring gas. The present work was measured the concentration of radioactive particles containing of exhaust gases from the accelerator for boron neutron capture therapy (BNCT).

EXPERIMENTAL

Gaseous radioactive particles were provided from the exhaust gas from the accelerator for BNCT. They were filtered with pre filter and heap filter, and then were used as monitoring gas. The atmosphere outside Innovation Research Laboratory was used as reference gas.

An activity of gaseous radioactive particles was measured by using radioactive gas monitor (Ohkura Electric Co., RD-1,200) and ion chamber (Ohkura Electric Co. I-409602, 1,000cm^3). The output of ion chamber was digitally recorded by a datalogger (Graphtec Co., midi LOGGER GL200).

RESULTS

The concentration of radioactive particles containing of exhaust gases from Accelerator for boron neutron capture therapy (BNCT) was continuously measured from October 25 (Sunday) in 2009 to February 2 (Tuesday) in 2010.

Figure 1 shows the concentrations of gaseous radioactive particles contained in the exhaust gas of the neutron generator from January 10 (Sunday) to January 30 (Saturday) in 2010. The concentrations of exhaust gas indicated several peaks. These peaks emarged within about 3 min. after the working of BNCT. While, the concentration of atmosphere was not affected by the working of BNCT.

The separation of tritium compounds from radioactive particles containing of exhaust gases from BNCT is expected in further experiment.

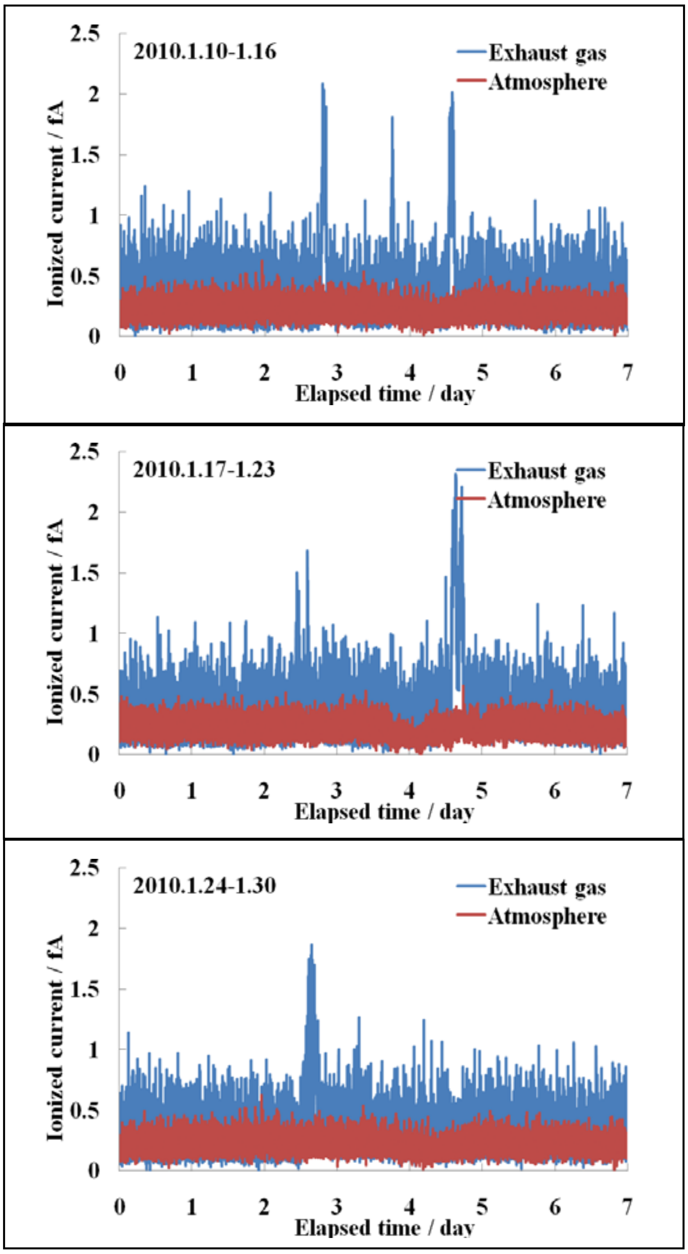

Fig. 1. The concentrations of gaseous radioactive particles contained in the exhaust gas of BNCT and atmosphere outside Innovation Research Laboratory.

採択課題番号 21P12-4　　加速器施設内外のトリチウム生成・動態評価　　プロジェクト

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PR12-5 Behavior of Colloidal Species Formed in the Cooling Water of Accelerator Facilities

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INTRODUCTION: In accelerator facilities, a management of cooling water is one of the important tasks. Purified water was often contaminated with metal ions and colloids associated with radionuclides during operation. For example, Be-7 is produced by spallation reaction of oxygen in water and associated with metal oxide colloids at the high-energy and high-intensity accelerators. However, colloid-formation processes in water is not clearly known. In this work, metals such as Fe, Cu and Al contacted with water were irradiated by γ-ray, bremsstrahlung and neutrons and colloid formation in water was investigated.

EXPERIMENTS:
(1) Irradiations at the electron LINAC

Irradiation was carried out using bremsstrahlung and neutrons generated by 30 MeV electron beam hitting on Ta target (*Φ*50x61.5 mm) using an electron linear accelerator (LINAC) at the KURRI. Pure water was sealed into the metal pipe (I. D.10.7x298mm; Pipe materials: Cu, Fe, Al). A pair of metal containers was fixed at the downstream position (0 deg: 40 mm from Ta target) for bremsstrahlung and neutron irradiation, and perpendicular position (90 deg: 20 mm from Ta target) for neutron irradiation. Electron beam current was about 100 μA, and the irradiation time was 4 hours.

After irradiation, water samples were collected and filtrated with four kinds of ultrafiltration (UF) units for particle size separation. Estimated pore sizes of the UF units were 200 nm, 16 nm, 7 nm, and 3nm. Each filtrate was acidified with nitric acid (0.5%), and concentration of metals were determined by graphite furnace AAS and ICP-AES analyses.

(2) Irradiations at the ^{60}Co gamma-ray irradiation facility

Mixtures of pure water (70 ml) and Cu metal powder (2.0 g, 100 μm) were sealed into glass vessels, and irradiated by several dose rates ranging 0-3.3kGy/h for 87h using the ^{60}Co gamma-ray irradiation facility at the KURRI. During irradiation, samples were stirred with a magnetic stirrer. Irradiated samples were treated in a similar manner as above and the concentrations of Cu in filtrates were analyzed by AAS.

RESULTS: Figure 1 shows the concentrations of Cu, Fe, and Al in case of the LINAC irradiation. High concentrations of Cu, Fe, and Al existed in water phase after irradiations. Especially at the 0 deg position, total metal concentrations were high and large particles were created. These results suggest that bremsstrahlung irradiation promotes not only corrosion of metal surfaces but generation and growth of colloidal metal species in water.

Figure 2 shows concentration profiles for Cu with and without γ-ray irradiations. Creation of large colloid was promoted by the high dose of γ-ray irradiation. Chemical form of colloidal species produced by γ-ray irradiation was identified with copper oxide (I) (Cu_2O) by the X-ray diffraction analyses. These results show that Cu material is dissolved and oxidized to Cu_2O as colloidal species.

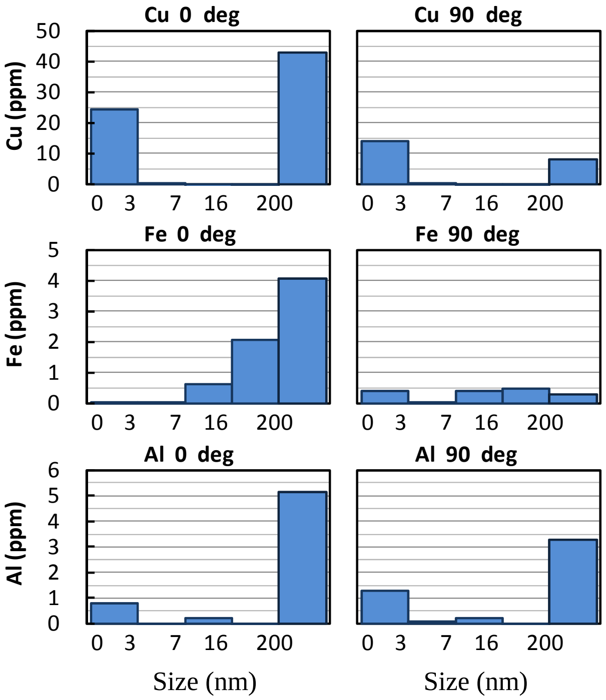

Fig. 1. Relationship between colloid size and colloidal concentrations of Cu, Fe, and Al in water after irradiations at the electron LINAC.

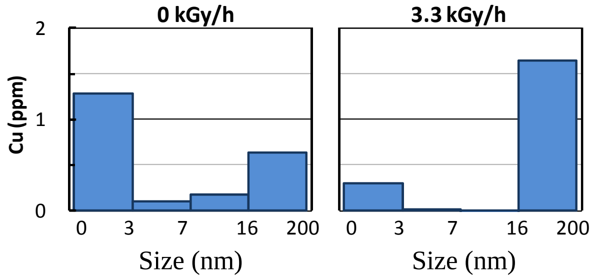

Fig. 2. Relationship between colloid size and colloidal concentrations of Cu in water after irradiations at the ^{60}Co gamma-ray irradiation facility.

Reaction time : 87 h

採択課題番号 21P12-5　加速器冷却水中における放射性核種およびコロイド化学種の挙動解析　プロジェクト

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PR12-6 Influence of Radioactive Gas on Size Measurement of Radioactive AerosolParticles by Diffusion Battery Method in Accelerator Facilities

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INTRODUCTION: Various airborne radioactive nuclides are formed in air of accelerator rooms during machine operation. The behavior of aerosols bearing thus formed radioactive atoms in radiation fields gives us useful information on both of aerosol creation in the atmosphere and radiation protection against inhalation of airborne radionuclides. Measurement for time variation of the particle size distribution of the aerosols is an effective way to clarify the behavior. However, the diffusion battery (DB) method [1], a typical size measurement technique for radioactive sub-micron particles, does not work correctly for the particles bearing ^{13}N, while the size of radioactive particles for principal nuclides in accelerators, such as ^{7}Be and ^{11}C, was successfully measured with the DB [2]. The particles bearing ^{13}N which is the principal radionuclide of electron linear accelerators (linacs) coexist with a large amount of ^{13}N gaseous species . The coexisting gas may interfere in exact measurement for the radioactive particles. In this work, influence of adsorption of radioactive gas was shown in the measurement with the DB.

EXPERIMENTS: The screen-type DB comprises the stack of stainless steel screens (mesh size: 500 wires per inch) and a collection filter placed at the rear of the stack. The membrane filter, DM-800 (Gelman Science), was used as the collection filter in this experiment. An air irradiation experiment was performed in the 46-MeV electron linear accelerator in the Research Reactor Institute of Kyoto University. Aerosol-free air was irradiated with bremsstrahlung of 30 MeV (max. energy). The activity of the collection filter was measured with a Ge semiconductor detector and a coincidence measurement system of BGO detectors for the annihilation γ-ray counting. The fraction of ^{13}N gas adsorbed on the membrane filter was separately determined using aerosol-free irradiated air prepared by filtration of air irradiated in the linac under the same condition.

RESULTS AND DISCUSSION: The behavior of the particles in the size range of nm to sub-micron is dominantly governed by diffusion of the particles. A part of the particles introduced to the screens is collected on the surface of the screen wires by diffusion. The rest part of the particles which penetrates the screen stack is trapped on the collection filter.

Activity of the filter was identified as ^{13}N at the beginning of the sampling by the decay analysis of the annihilation peak. The size distribution of the aerosol particles was assumed to have a lognormal distribution. The concentrations of particles penetrating the screens are expressed by an integral of multiplication of the penetration ratio (the ratio of activity penetrating the screens to activity introduced to the screens) and size distribution. The size distributions of ^{13}N-bearing particles were derived by fitting the curve of the penetration ratio obtained by changing the number of screens of the DB [2].

The obtained size distribution for the ^{13}N-bearing particles is shown in Fig. 1 along with that of whole aerosol particles including non-radioactive particles. The size distribution for the whole particles was obtained by replacing activity with the number concentration of the particles in the penetration ratio. It was observed that the ^{13}N distribution was much broadened compared with that for the whole particles. The adsorption fraction of the ^{13}N gas for DM-800 was found to be in the range of 3.2 to 31 %, depending on the flow rate of the sample air. The distribution was recalculated by considering the gas adsorption on the filter. The correction was made, assuming 20 % of the gas adsorption fraction. As shown in Fig. 1, the broadening was not observed in the corrected distribution. It is indicated that the broadening is attributed to the gas adsorption. Filters little affected by the coexisting ^{13}N gas, such as PTFE membrane filters, are suitable for aerosol collection in size measurement of radioactive aerosol particles in accelerator rooms.

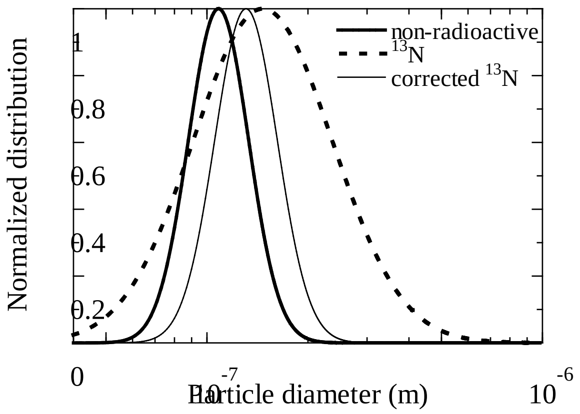

Fig. 1. The size distribution of the aerosols obtained in the linac

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[2] K. Kondo, H. Muramatsu, Y. Kanda and S. Takahara, Int. J. Appl. Radiat. Isot., **35** (1984) 939.

採択課題番号 21P12-6　　大強度加速器内で発生する放射性ガスの性状測定　　プロジェクト研究
（京大・原子炉）沖　雄一、関本俊、山崎敬三、丸橋晃、（京大院・工）長田直之
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PR12-7 Influence of Collectiong Substrates on Size Distribution Measurement of N-13 and Rn-Progeny by Low Pressure Cascade Impactor in the Linac Facility

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INTRODUCTION: At high energy accelerators like FFAG (max. energy 150 MeV, max. average current 1 nA), the radiation protection toward the induced airborne particulate radio-nuclides is one of the key issues for radiation safety of workers. Ultra fine particle generation and induced particulate radioactivity in high energy and high dose accelerator radiation field have been Co-60 gamma irradiation facility and Linac in KUR. This report describes mainly the experimental results which were obtained in the target room of Linac.

EXPERIMENTS: Exposure experiments were carried out in the ambient air of the target room. The ventilation of the room was stopped during experiment. The accelerator was operated at the condition of maximum energy 30 MeV and maximum average current 90 μA. The target material was Ta. The sampling point was about 1 m apart from the target and about 1 m high from floor. The sample air which was irradiated by high energy bremsstrahlump and neutron was introduced to the experimental room using flexible tubing made of stainless steel of 2.5 cm dia. and about 6 m in length through the radiation of 2.5 m thick concrete. Sampling flow rate was about 25 ℓ/min. Number size distribution and activity-weighted size distribution which were induced by high dose and high energy accelerator radiation were measured using SMPS (TSI, Model 3936), CPC (TSI, Model 3025A), laser particle counter (RION, KC-18) and low pressure cascade impactor (Tokyo Dylec, LP-20RS)

Collecting substrates that was used in this study were
(1) Uncoated clean stainless steel plate (Uncoated SUS)
(2) Dow Corning silicone grease coated stainless steel plate (Grease coated SUS)
(3) Soft silicone rubber sheet with 0.5 mm thickness

The aerosol attached N-13 and Rn-progeny were sampled on each stage of the impactor for thirty minutes with flow rate of 22.2 liters per minutes. The beta ray from N-13 and the alpha particles from Rn-progeny were sequentially measured with on automatic sample changer (Aloka, Model JDC-551S) equipped with ZnS scintillation counter and GM counter for 1 minute after 15 minutes waiting for the decay of ^{218}Po. After decay correction, number fractions of radioactive particles were found for each stage of the impactor. Since the size distribution was close to a log-normal distribution, the data of the cumulative fraction vs. the aerodynamic diameter were plotted on a logarithmic probability section paper. The smooth line through those data points was used to find the geometric median diameter (GMD, d_g), and geometric standard deviation (GSD, σ_g).

RESULTS and DISCUSSIONS: Table 1 shows typical values of the size distribution parameters of N-13 and Rn-progeny aerosols in the target room of the Linac for several collecting substrates. Here, N-13 radioactive aerosol which exists in the target room in the machine operation is considered to coexist with large amount of gaseous N-13. Gaseous N-13 may exist in the form of Nitrogen-oxide such as NO, NO_2, NO_3 etc.

The Values in the Table 1 shows that these gaseous components may react with the silicone which is included in the silicone grease and silicone rubber.

Table 1. Typical size distribution parameters of the N-13 and Rn-progeny aerosols in the target room of the Linac for several collecting substrates.

Collecting Substrate	N-13		Rn-progeny	
	d_g(μm)	σ_g(－)	d_g(μm)	σ_g(－)
Uncoated SUS	0.19	2.32	0.25	2.38
Grease Coated SUS	0.37	1.76	0.36	1.60
Soft Si. Rubber Sheet	0.30	2.77	0.26	2.13

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