Study and Search for Main Reason of Lung Cancers Based on Cherenkov Radiation in Environmental Radiation

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***Abstract*—The number of lung-cancer-related death is highest among all cancers death in the world, and it is increasing in Japan where population aging in progressing. The main reason for the lung cancer of non-smokers is regarded to be environmental pollution or exposure of the lung to radon in the nature. The risk of lung cancer was estimated to increase by 8 to 13% per every rising $100\,\mathrm{Bq\,m^{-3}}$ concentration of radon in the air. We observed beta rays with maximum energy of 3.27 MeV emitted from ^{214}Bi as one of the progenies based on a detection of Cherenkov radiation. The surface radioactivity concentration of ^{214}Bi on the sample depending on time that the sample was exposed in windless roomair was measured. The behavior of the radon progenies in the air is discussed by a research for the progenies attaching on the sample after the radon decay. The inhalation of the radon progenies is not clear. Thus, understanding the behavior of progenies in the air makes to clear the causal relation between the radon concentration and lung cancers.**

***Index Terms*—Radon Progenies, Bismuth-214, Cherenkov Radiation**

I. Introduction

THE number of lung-cancer-related death is highest among all cancers death in the world, and it is increasing in Japan where population aging in progressing [1]. Although the primal cause of lung cancer is considered to be smoking, non-smokers also suffer from the lung cancers. The main reason for the lung cancer of non-smokers is regarded to be environmental pollution or exposure of the lung to radon in the nature [3], [4]. The risk of lung cancer was estimated to increase by 8 to 13% per every rising $100\,\mathrm{Bq\,m^{-3}}$ of radon concentration in the air, which was extracted from the relation between the lung-cancer patient rate and the radon concentration in the North American, European, and Chinese [5]. Therefore, the radon inhalation is a strong candidate for the occurring of the lung cancer in the nature.

The average of annual radioactive dose is estimated as $1.15\ \mathrm{mSv}$ from the $^{222}\mathrm{Rn}$ inhalation at the mean concentration of $45\ \mathrm{Bq\,m^{-3}}$ in the air [6]. This value depends on the equilibrium factor after the radon is inhaled [7], which is assumed to be 0.4, for radon progenies of $^{218}\mathrm{Po}$, $^{214}\mathrm{Pb}$, $^{214}\mathrm{Bi}$, and $^{214}\mathrm{Po}$ in radon decaying. However, it is not clear in the papers [6], [8] in a case that these progenies float in the air and are inhaled. Namely, the behavior of radon progenies have been not understood after radon decay in the air. If this behavior is cleared, the inhalation radiative dose can be estimated more in precise.

The ^{214}Bi, which emit beta rays (maximum kinetic energy of 3.27 MeV) are focused in this study. The radioactivity concentration of ^{214}Bi can be estimated by measuring the beta rays based on Cherenkov radiation detection. In this paper, the behavior of the radon progenies in the air is discussed by a research for the progenies attaching on the sample after the radon decay.

II. Experiment

The experimental setup is shown in Fig. 1. The sample (polyethlene) is set under the scintillating fibers after it was exposed in windless roomair. The radon progenies falls on the sample by exposing in the roomair after the radon decay. The scintillating fiber (Kuraray, SCSF-78MJ, ϕ 0.2 mm) emits photons when the charged particles deposit energies there. The fibers are assembled to a sheet with an effective area of 10 $\times$ 10 cm^2. The photons propagating by a total reflection in the fibers are observed by photomultiplier tubes (PMT): PMT1 and PMT2 (Hamamatsu, R9880U-210), which are connected to both ends of the fibers. A Cherenkov detector using silica aerogel was set over the scintillating fibers. The aerogel (a refractive index of 1.041$\pm$0.001, the size of 9.6$\times$9.6$\times$1 cm^3) emits Cherenkov photons by a beta ray with kinetic energy over 1.31 MeV. The photons are lead to PMT3 or 4 (Hamamatsu, R1250-03 and H6528) by a reflector with aluminised Mylar and are observed. The black paper is set under the silica aerogel because the Cherenkov light originated from cosmic muons must not be reflected. The scintillation detector was set over the Cherenkov detector. It consists of a plastic scintillator (the size of 10$\times$10$\times$0.5 cm^3), acrylic light guide, and PMT (Hamamatsu, H1161). To suppress events related to cosmic muon, the cosmic-ray veto counter was set over aluminium plate with thick of 1 cm. The veto counter consists of a plastic scintillator (the size of 10$\times$20$\times$0.5 cm^3), acrylic light guides, and PMT6, 7 (Hamamtsu, H1161). The PMTs connected to both ends of the scintillator via the light guides.

Therefore, the beta rays originated from ^{214}Bi can be observed as events when the coincidence fulfills followings: hit the scintillating fibers, emitted Cherenkov radiation, hit the scintillator detector, and not hit the veto counter.

Manuscript received 15 July, 2017.
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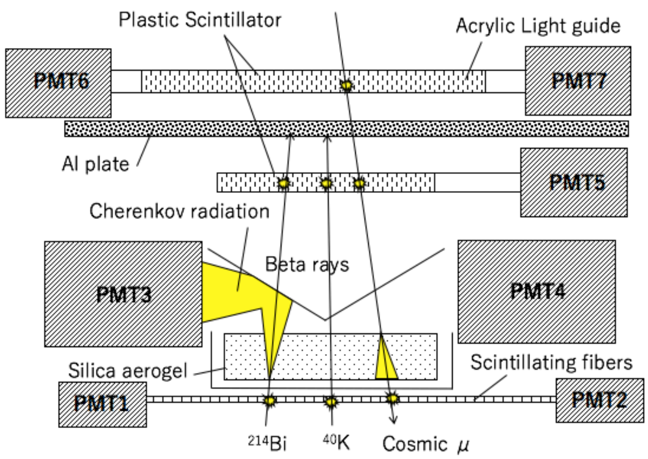

Fig. 1. A schematic of experimental setup.

III. Results and Discussions

The sample was exposed for 1 h 20 min in windless roomair. In this experimental, the PMTs count if the number of photoelectrons N_j is over 0.5 p.e., i.e., $C_j = 1$ ($N_j > 0.5$ p.e.) or 0 (other) in PMTj. (a) The counting logic for β rays from the sample without cosmic rays was given as

$$C_1 \cdot C_2 \cdot \overline{(C_6 + C_7)}, \quad (1)$$

The 10 min counting rates are shown in shown in Fig. 2. (top). The black and red open circles are data of background and for the sample setting, respectively. The redline is a fitting function of $A\exp(-x/\tau) + R_{\mathrm{BG}}$, where $A = 1.29 \pm 0.07$, $\tau = 0.98 \pm 0.07$, and $R_{\mathrm{BG}} = 4.87 \pm 0.01$. Therefore, this decay term suggests the radionuclides with short life which emitted β rays attached on the sample surface. (b) The counting logic for β rays from ^{214}Bi on the sample without cosmic rays based on Cherenkov radiation was given as

$$C_1 \cdot C_2 \cdot (C_3 + C_4) \cdot \overline{(C_6 + C_7)}, \quad (2)$$

The 10 min counting rates are shown in shown in Fig. 2. (bottom). The black and red open circles are data of background and for the sample setting, respectively. The redline is a fitting function of $A\exp(-x/\tau) + R_{\mathrm{BG}}$, where $A = 1.48 \pm 0.10$, $\tau = 1.99 \pm 0.19$, and $R_{\mathrm{BG}} = 0.61 \pm 0.01$. The blue dashed area indicates the event that Cherenkov photons emitted by the ^{214}Bi β rays clearly.

In this blue dashed area, the total number distribution of photoelectrons $N_{\mathrm{p.e.}}$ of PMT3 and 4 is shown in Fig. 3 (top). The black and red histograms are the background and sample data, respectively. The difference with the black and red histograms suggests the signal of origin from Cherenkov radiation by ^{214}Bi β rays. The difference is shown in Fig. 3 (bottom). The red line is a Poisson function fitting, $AP(N_{\mathrm{p.e.}}, \nu)$, where ν corresponds to mean number of photoelectrons and $P(k, \nu) = e^{-\nu}\nu^k/k!$. The fitting parameters were determined to be $A = (1.33 \pm 0.01) \times 10^3$, $\nu = 0.533 \pm 0.001$ with $\chi^2_m in/NDF = 1027/32$. As a result, Cherenkov photons originated from ^{214}Bi β rays were observed on the polyethylene sample surface in roomair.

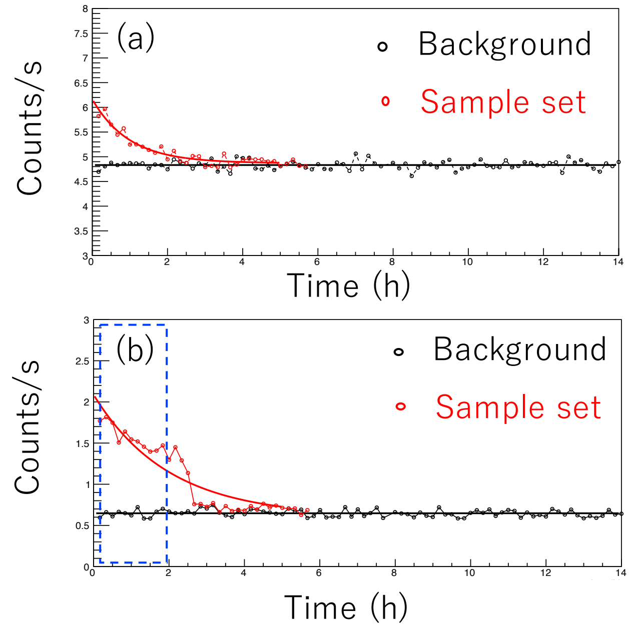

Fig. 2. (a) The trigger and not veto counting events (top) and (b) further Cherenkov photons counting events (bottom). The count rates for the polyethylene sample put for 1 h 20 min in the windless roomair (red) and background (black).

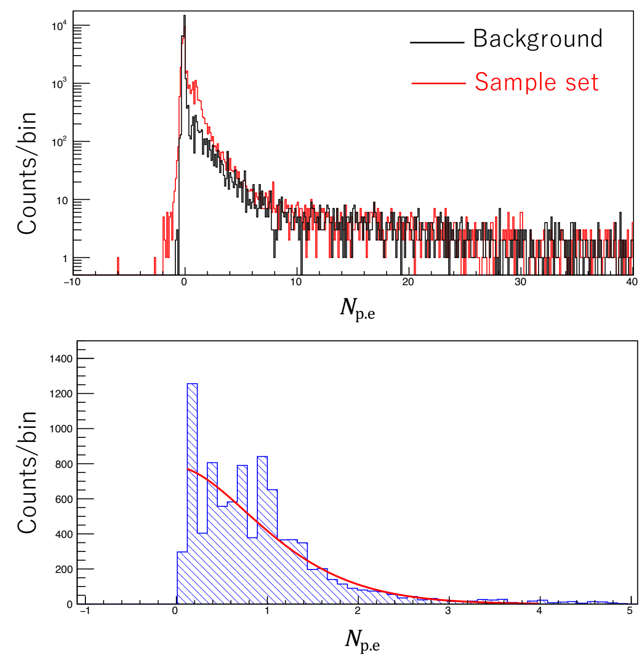

Fig. 3. The relation between the radioactivity concentration and exposure time.

IV. Summary

The radon progenies in the air is focused by the recent study. The research of a behavior of radon progenies shows a study and search of main reason of lung cancers. In the study, the β rays from ^{214}Bi attached on the sample surface in roomair were detected based on Cherenkov radiation. In future, the concentration of ^{214}Bi will be measured and the behavior of radon progenies will be made clear in the air.

REFERENCES

[1] Foundation for Promotion of Cancer Research, Cancer statistics in Japan 2015.

[2] I. Funatogawa, T. Funatogawa, E. Yano, Bull World Health Organ, 91 (2013) 332-340.

[3] J. Subramanianand, R. Govindan, Lung Cancer in Never Smokers: A Review, J. Clin. Oncol., 25 (2007) 561-570.

[4] J. M. Samet, E. Avila-Tang, P. Boffetta, L. M. Hannan, S. Olivo-Marston, M. J. Thun, C. M. Rudin, Lung Cancer in Never Smokers: Clinical Epidemiology and Environmental Risk Factors, Clin. Cancer. Res. 15 (18) (2009) 5626-5645.

[5] H. Choi, P. Mazzone, Radon and lung cancer: Assessing and mitigating the risk, Clev. Cli. J. 81 (9) (2014) 567-575.

[6] UNSCEAR 2008 report vol. 1, Source effects and risks of ionizing radiation.

[7] J. E. Martinez, B. Juste, J. Ortiz, S. Martorell, G. Verdu, Air Radon equilibrium factor measurement in a Waste Water Pre-Treatment Plant, Rad. Phys. Chem. (2017). <https://doi.org/10.1016/j.radphyschem.2017.03.011>.

[8] ICRP publication 71 (1995).