Growth and Decay of Alpha Tracks in a Large Scale Cloud Chamber after Injection of Radon

Shinichi Wada [a], Tsuneo Kobayashi[b], Yoshiro Katayama[c], Toshiaki Iwami[d], Tsuguhisa Kato[e], John R. Cameron[f]

[a] Dept. of Radiological Technology, Faculty of Medicine ,Niigata University, Niigata,951-8518, Japan, [b]Dept. of Physics, School of Medicine, Fukushima Medical University, Fukushima, 960-1295, Japan, [c]ProTec Inc., Saitama, 341-0037,Japan, [d]Niigata Kounan High School, Niigata, 950-0948,Japan, [e] Tokyo Metropolitan University of Health Sciences, Tokyo, 116-8551,Japan, [f] Dept. of Medical Physics, University of Wisconsin-Madison, WI, 53706-1532, *USA*
e-mail:swada@clg.niigata-u.ac.jp

ABSTRACT

The recognition of the natural background radiation is important not only for radiological education but also for the promotion of people's scientific view about radiation. We made a "room" on the web showing natural background radiation as part of a VRM (Virtual Radiation Museum). The "room" shows the video images of the tracks of charged particles from natural background radiation, alpha and beta ray track from known sources using a Large Scale Diffusion Cloud Chamber. The purpose of this study is to make clear the origin of a kind of track (named A-track) which is thick and easy to recognize with the length less than several cm in the cloud chamber, and to make numerical explanation of its counting rate. The study was carried out using a Large Scale Diffusion Cloud Chamber (Phywe, Germany) installed in the Niigata Science Museum. The Model RNC (Pylon Electronics, Canada) was used as Rn-222 source. Ra-226 activity in RNC was 111.6 Bq calibrated with NIST protocol. Rn-222 gas was injected into the cloud chamber. Continuous video recording with use of Digital Handycam (SONY, Japan) was carried out for 360 min. after injection of Rn-222 gas. The number of alpha-ray track (alpha track) in the video images was analyzed. The growth and decay curve of the total activity of Rn-222 and its alpha emitting progeny were calculated and compared with the count of the alpha tracks. As a result the alpha tracks formed by Rn-222 injection resemble A-Tracks. The relationship between A-track in the cloud chamber and atmospheric Rn is discussed.

Keywords: Natural background radiation, Virtual Radiation Museum, Cloud Chamber, Rn.

1. INTRODUCTION

A Cloud Camber is useful to visually demonstrate ionizing radiation. The Large Scale Diffusion Cloud Chamber (LSDCC) is especially good for this purpose. It shows detail of tracks from natural background radiation or from cosmic rays. It can also be used to show tracks from radon gas injected into the Cloud Chamber. The Cloud Chamber will be the main feature of a "room" in a Virtual Radiation Museum on the web. It will show tracks from natural background radiation to help people's understanding of ionizing radiation. The "room" shows the video images of the tracks formed by charged particle from cosmic rays or other radiations in the LSDCC installed at NIIGATA SCIENCE MUSEUM[1)] (NIIGATA, JAPAN). Many kinds of natural tracks are continuously observed in the LSDCC. Among them an easily visible thick track with a range of less than 5 or 6 cm was tentatively labeled an A-track. The appearance of the tracks with several cm of the range suggests that it may be an alpha particle from Rn. But can the relatively high count rate be reasonably explained? How does the Rn get into the "closed space" of the chamber box? How does it compare with the atmospheric Radon concentration? This study was carried out to find answers to such questions.

2. MATERIALS AND METHODS

2.1. Cloud chamber and experimental setup.

The Large Scale Diffusion Cloud Chamber used in this study is PJ-80 (PHYWE: GERMANY) installed at Niigata Science Museum (NIIGATA, JAPAN). The cloud chamber consists of a base and an observation chamber.

The chamber base comprises a cooling unit, power supply, an alcohol reservoir and an alcohol pump. The observation chamber is placed onto the chamber base. At the bottom of the observation chamber black metal plate is cooled over its whole surface to about –30° C. A grid of fine heating wires is placed between the upper two glass plates. These wires

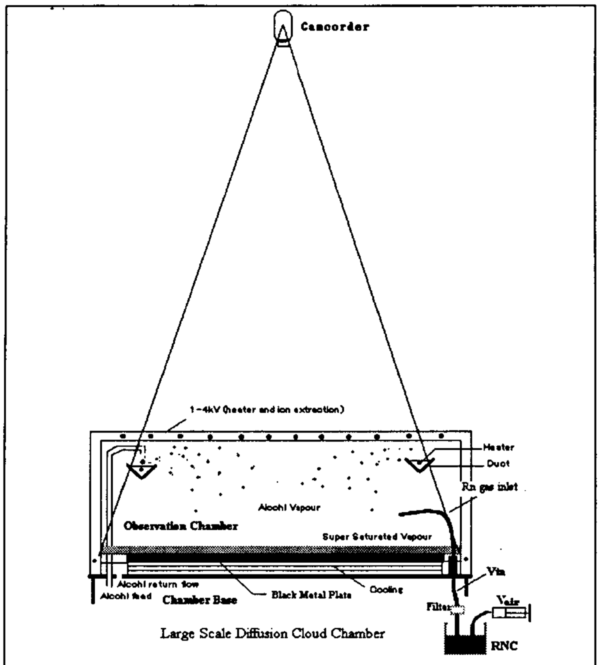

Fig.1: Experimental setup

heat this area of the chamber. At the same time they apply a high electric field to extract ions. Iso-propyl alcohol was supplied by alcohol pump into gutter. The volume of the observation chamber is 1.0*1.0*0.2 [m^3]. The thickness of the supersaturated layer is a few cm. The Model RNC (Pylon Electrics, Canada) was used as a calibrated Radon gas source traceable to NIST standards. The radioactivity of Rn-222 on the date of experiment was 110Bq. Rn gas was injected from RNC into the cloud chamber through the connected tube with a syringe (Fig.1). The filter was used to exclude Rn-222 progeny.

2. 2. Growth and decay of alpha track

When the volume of RNC, air volume of injected by syringe and the tube volume between RNC and cloud chamber are denoted as V_{RNC}, Vair and Vta respectively, the injected activity of Rn-222 (A_{Rn}^0) may be given

$A_{Rn}^0 = 110 * Vair / (Vair + V_{RNC} + Vta)$ .... (1)

The activity of Rn and its progeny will grow according to the equations:

$dN_{Rn-222}/dt = -\lambda_{Rn-222} N_{Rn-222}$, ... (2)

$dN_{Po-218}/dt = \lambda_{Rn-222} N_{Rn-222} - \lambda_{Po-218} N_{Po-218}$ .... (3)

$dN_{Pb-214}/dt = \lambda_{Po-218} N_{Po-218} - \lambda_{Pb-214} N_{Pb-214}$ ....(4)

$dN_{Bi-214}/dt = \lambda_{Pb-214} N_{Pb-214} - \lambda_{Bi-214} N_{Bi-214}$ .... (5)

$dN_{Po-214}/dt = \lambda_{Bi-214} N_{Bi-214} - \lambda_{Po-214} N_{Po-214}$ ....(6)

$dN_{Pb-210}/dt = \lambda_{Po-214} N_{Po-214} - \lambda_{Pb-210} N_{Pb-210}$ ....(7)

Where λ_{Rn-222}, λ_{Po-218}, λ_{Pb-214}, λ_{Bi-214}, λ_{Po-214} and λ_{Pb-210} are the decay constants of Rn-222, Po-218, Pb-214, Bi-214, Po-214 and Pb-210 respectively. The radioactivity of each element i is $A_i = \lambda_i * N_i$. Alpha emitters are Rn-222, Po-218 and Po-214. Then the growth curve of the concentration (Bq/m3) of Alpha-emitter was calculated.

2. 3. Counting of alpha track and comparison with calculated growth curve.

Continuous video recording with a camcorder (Digital Handycam SONY, Japan) 116cm above the top of the cloud chamber (Fig.1) was carried out for 360 min. after injection of Rn-222 gas. Each 5 seconds of video image were converted to 150 frames of bit map images (30 frames per second, 320*240matrics). Every 10 frames image were analyzed to count alpha tracks per sec with use of subtraction of an images to the image 1/3 seconds delay. The video data on 10,20,30,40,50,60,120,240 and360 minutes after Rn-gas injection, and the data 5 minutes before injection were analyzed. The field of view of the video image was 0.87m^2 at the supersaturated layer. The effective volume sensitive to alpha track (Vs) is 0.87Ts m^3 where Ts is the effective thickness of the supersaturated layer. The tentative estimation of the alpha emitter concentration (R^*_C: Bq/m^3) was made with the following equation:

$R^*_C = C_A / Vs * \xi x$ ....(8)

Where C_A is the counting rate of alpha tracks in the video image per second. And ξx is a tentative normalization factor to fit theoretical curve at 10 min. after injection.

3. RESULTS AND DISCUSSION

3.1. Comparison of A-track with the alpha track formed after the injection of Rn-222 gas.

The experiment was carried out under the conditions with V_{RNC}=66.3cc,Vair=50cc, Vta=25cc. The injected Rn-222 gas was supposed to 39Bq according to equation (1). Fig.2 show the images of the cloud chamber.

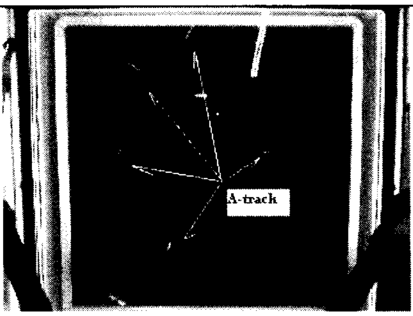

Fig2. (a)Before injection (background)
Arrows show A-tracks.

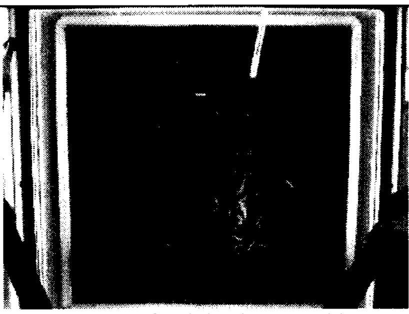

Fig2. (b) Just after injecting Rn-222

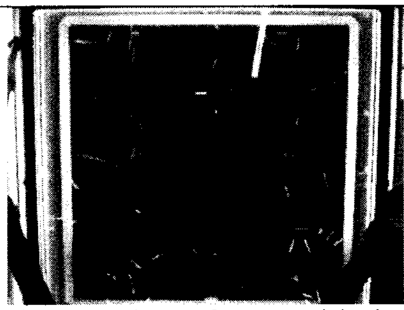

Fig2.(c) 10minutes after Rn-gas injection.

Fig.2-a shows A-tracks in the cloud chamber. Fig2-b shows many alpha-tracks with injection of Rn-222 gas. Fig.2-c shows many alpha tracks spreading all over the chamber field. A-track resembles alpha-track from Rn-222 or its progeny.

3.2. Comparison with calculated growth curves and the number of the alpha tracks from Rn-222.

Fig.3 shows two samples of subtracted image. The black short tracks without white line surroundings shows the new tracks made on the time interval of 1/3 sec.

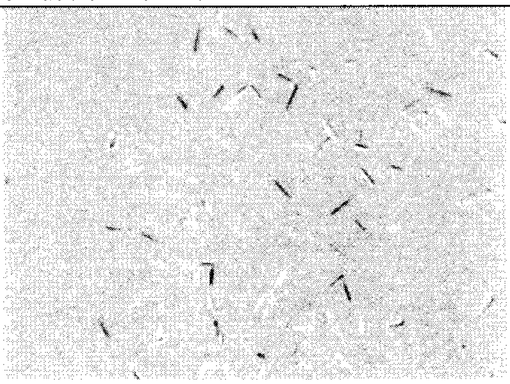

Fig.3-a A sample of subtraction image (20min: 10fr- 20fr).
This case was counted as 20counts/(1/30sec).

Fig.3-b 360min: 100fr-110fr

Subtraction was made between 2-images taken 1/3 seconds interval. Black lines without white surroundings were counted as new tracks appeared within 1/3seconds of time interval. Additional check of two original images was made.

Table.1 shows the results of the counting rate of A-tracks or alpha tracks on video image.

C_A	-5min	10min	20min	30min	40min	50min	60min	120min	240min	360min
Counts /sec	1.6	40.2	46.0	42.6	44.6	48	50	56	46.6	42.8
error (%)	14.3	7.0	6.6	6.9	6.7	6.5	6.3	6.0	6.5	6.8

Table.1 Counting rate (C_A) on -5min shows that of A-track. The others are C_A s of alpha track including A-track. The field of view is 0.87m^2.

Fig.4 shows the calculated results of radioactive concentration of the Rn-222 and progeny. The calculation was made under the following assumptions.

1) The distribution of Rn-222 and progeny is uniform in the observation chamber.
2) The observation chamber is sealed for Radon gas or progeny.
3) The A_{Rn}^0 is 195Bq / m^3 (39Bq/0.2m^3).

The plots in Fig.4 (○: R^*_C) for alpha tracks were made with the suppositions of

1) The effective thickness of the super saturated layer Ts is assumed to be 30mm.

2) A tentative normalization factor ξx resulted 1/4.
3) The counting rate of A-track was subtracted from that of alpha track in the usual manner for background using the data of -5min.

Although the counting rate of alpha track after Radon gas injection grew up rapidly, subsequent concentration decreased isolating to the calculated curve of alpha emitters of Radon and its progeny.

3.3. Discussion

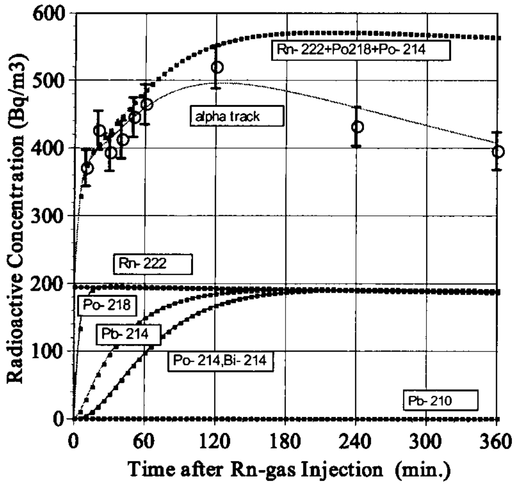

Fig.4. Radioactive concentration of Rn-222 and progeny (A_{Rn}^0 =39Bq). Radioactive concentration of Alpha emitters were derived using measured alpha track counting rate with assumptions Ts=30mm, ξx =1/4.0 and uniform distribution of alpha emitter.

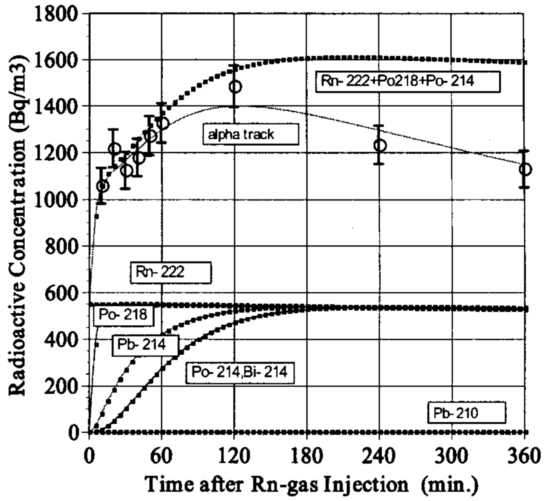

Fig.5. Calculation made with A_{Rn}^0 =110Bq. Alpha track counting rate was converted to radioactive concentration with the assumptions of Ts=43mm, ξx =1 and uniform distribution of alpha emitter in the chamber.

The alpha track counting rate disagrees with the theoretical growth and decay curve for the radioactivity of Rn-222 and its progeny in the closed space. The intensity of the observed tracks was much more than expected. The effective thickness of supersaturated layer for alpha track is supposed to be 30 mm. But the tentative normalization factor ξx=1/4 was difficult to explain. The initial activity of injected Rn-222 A_{Rn}^0 was supposed to be 39Bq. The experimental setup still needs improvements to accurately determine the amount of injected Rn-222 activity. Fig.5 shows the calculated results if A_{Rn}^0 were 110Bq. On the plot of measured alpha track intensity the normalization factor ξx=1.0 with effective thickness of supersaturated layer with 43mm. The decrease of observed alpha track intensity suggests that the cloud chamber is not the closed space system for Rn-222 and progeny. If atmospheric radon-gas can penetrate into the chamber, it may convenient to explain why the A-track is observed so frequently in the cloud chamber. A-track concentration 1.6 counts/sec of in 0.87Ts means 43Bq/m^3 when Ts is supposed 43mm. On the other hand the mean Radon concentration[2)] at Niigata Science Museum measured by CPRD (Pylon: CANADA) is 52Bq/m^3. Further study will be needed to confirm the relationship between A-track and atmospheric Rn-222 concentration.

REFERENCES

1. Niigata Science Museum: "One point lecture: Cosmic rays, alpha lays: as a "room" of VRM", http://www. Lalanet.gr.jp/nsm/ index2.html, 2000-2001.
2. S. Wada, T. Kobayashi, T. Iwami, Y.Nakazawa, "A Comparison of Atmospheric Radon Concentration and Alpha Track Frequency in Large Scale Cloud Chamber", JJMP **22 sup2**, pp244-245,2002