

# Serial measurements of natural radiation in Fukushima through 2011 off the Pacific coast of Tohoku Earthquake, tsunami, and subsequent nuclear power plant crisis

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An earthquake, Tohoku region Pacific Coast earthquake, occurred on 11-March-2011, and subsequent Fukushima nuclear power plant accidents have been stirring natural radiations around the author's office. Fukushima Medical University is located in Fukushima city, and is 57 km (35 miles) away from northwest of the Fukushima Daiichi nuclear power plant. Gamma radiation in air with NaI scintillation counter, atmospheric radon with Lucas cell, and second cosmic rays with NaI scintillation counter have been serially measured through the accidents. Gamma radiation indicated most drastic change, i.e., peak value of 9.3 times as usual level occurred on March 16, and exponentially decreased to 1.7 times of usual level after two months. A nonlinear least square fit to this gave short half-life of 3.3 days and long half-life of 67 days. These two apparent half-lives will be attributed to radioisotopes of I-131 and Cs-137 or Sr-90, respectively. Also, atmospheric radon concentration became high because of a stop of ventilation, while second cosmic rays did not show any response.

**Keywords:** natural radiation, earthquake, nuclear power plant crisis, atmospheric gamma radiation, atmospheric radon, second cosmic rays

## 1. Introduction

When the Tohoku region Pacific Coast earthquake occurred on 11-March-2011, and Fukushima nuclear power plant accidents broke out subsequently, the present author had been measuring several natural radiations<sup>1</sup> around his office in Fukushima Medical University. It is located in the northeastern region of Japan (37°45'N, 140°28'E, 67.4 m above sea level), and is 57 km (35 miles) away from northwest of the Fukushima Daiichi nuclear power plant.

The natural radiations of the serial measurement are: gamma radiation in air with NaI scintillation counter, atmospheric radon with Lucas cell, and second cosmic rays with another NaI scintillation counter.

Amongst the results of serial observation, gamma radiation showed the most drastic change, i.e., peak value of 9.3 times as usual level occurred on March 16, and exponentially decreased to 1.7 times of usual level after two months. A nonlinear least square fit to these data resulted short half-life of 3.3 days and long half-life of 67 days. The first apparently short half-life (later referred as HL) is attributed to the existence of I-131 (HL: 8 days), while the second long HL may be contributions from nuclides of Cs-134 (HL: 2 years), Cs-137 (HL: 30 years) and Sr-90 (HL: 28.1 years). Also, the atmospheric radon concentration at the other place became high because of a stop of ventilation. Atmospheric radon at other places and second cosmic rays did not show any distinct response.

## 2. Materials and Methods

### 2.1 NaI scintillation counter

A 3"x3" NaI(Tl) scintillation detector (Teledyne S-1212-T, 7% resolution for Cs-137) had been observing gamma radiation in air at the author's office since October 2010. Every four-time integration of MCA data were stored in a computer. The present report discusses only gross dose rate expressed as a unit of cps. The room was on the fourth floor of the five storied concrete building.

### 2.2 Continuous Passive Radon Detector

A passive type Lucas cell detector (Pylon, AB-5) at several places (the author's office room, students' lab and the Radioisotope Center) had been measuring atmospheric radon concentrations. One-hour integrated data were stored in AB-5 or printed out to papers.

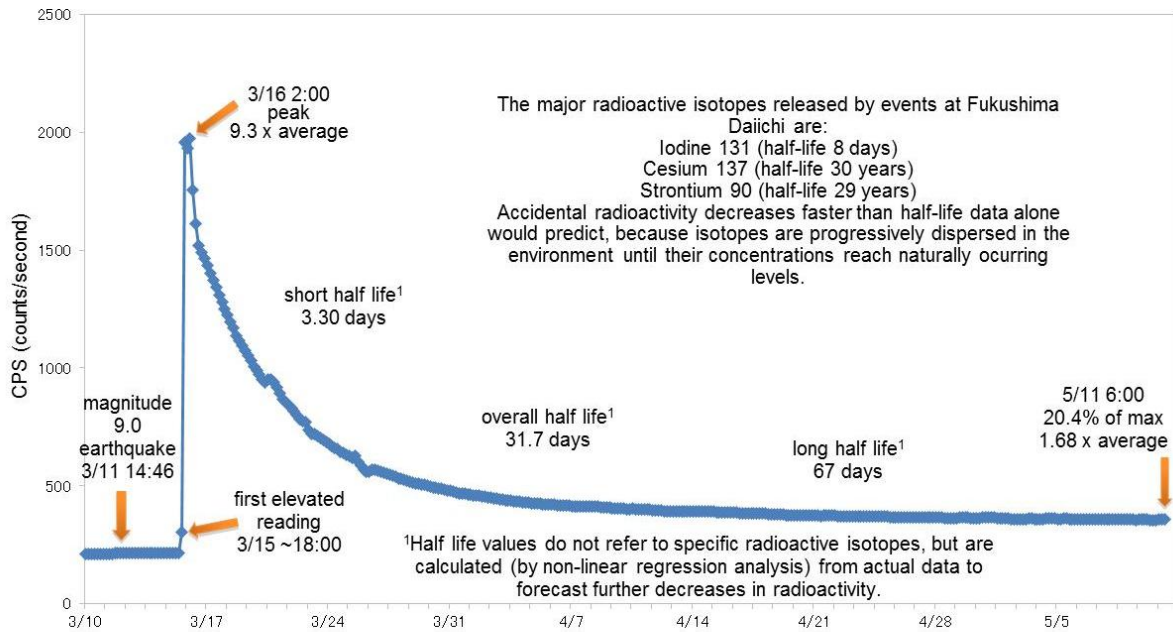
## 3. Results

### 3.1 Gamma radiation in air

Figure 1 shows gamma radiations with the NaI(Tl) scintillation detector. Just when the magnitude 9.0 earthquake happened, there was no change for the counts. As indicated in the figure, radiation dose reading began to elevate about 18:00 on the 15th of April and reached the maximum value of 9.3 times as usual values. This sudden increase was attributed to the hydrogen explosion at the nuclear power plant. Thereafter, the counts seemed to attenuate exponentially. This early exponential attenuation was expressed roughly 3 days of HL that is attributed to the existence of I-131 (HL: 8.06 days). This early environmental HL of 3 days was reasonably shorter than the physical HL of I-131.

After one month has passed, semi-log plot of the cps did not fit to a single line and the apparent HL became longer and longer, indicating the appearance of the second long HL. Thus, the author tried a model equation of

$CPS = a \cdot 2^{-(t/Ta)} + b \cdot 2^{-(t/Tb)}$ , where  $Ta$  is the short HL and  $Tb$  denotes the longer HL. Nonlinear least squares fit (using a command, nls, of S-PLUS<sup>2</sup> or R<sup>3</sup>) obtained the value of  $Ta = 3.30$  days and  $Tb = 67$  days. This second longer HL increased longer and longer afterwards and reached 102 days after about two months (83.25 days after the peak value was observed). This long HL might be contributions of newly supplied radioisotopes from nuclear reactor. The value of  $b/(a + b)$  was 0.15 that means long HL radioisotopes were 15% at the first explosion of the reactor.



Serial radiation measurements before and after the magnitude 9.0 earthquake, tsunami, and subsequent nuclear power plant crisis. Radiation surveillance is a routine activity of this department.

Figure 1. Gamma radiation in air with NaI(Tl) scintillation detector.

### 3.2 Atmospheric radon

Figure 2 shows the change of atmospheric radon in one room of the Radioisotope Center. This Center is normally ventilated extremely because of the prevention of non-sealed radioisotopes. This extreme ventilation stopped when the earthquake broke out and RI users were immediately prohibited to enter. The stop of ventilation naturally raised atmospheric radon concentration as indicated in the Figure 2.

Usual radon level was quite low and less than the lower detection limit of the device ( $5 \text{ Bq/m}^3$ ), while after the ventilation stopped, it raised as high as  $250 \text{ Bq/m}^3$  that exceeds intervention level of the U.S.A. ( $150 \text{ Bq/m}^3$ ) or Europe ( $200 \text{ Bq/m}^3$ ). Although the level became high, there was no problem of radiation protection because people were inhibited to enter during the accident.

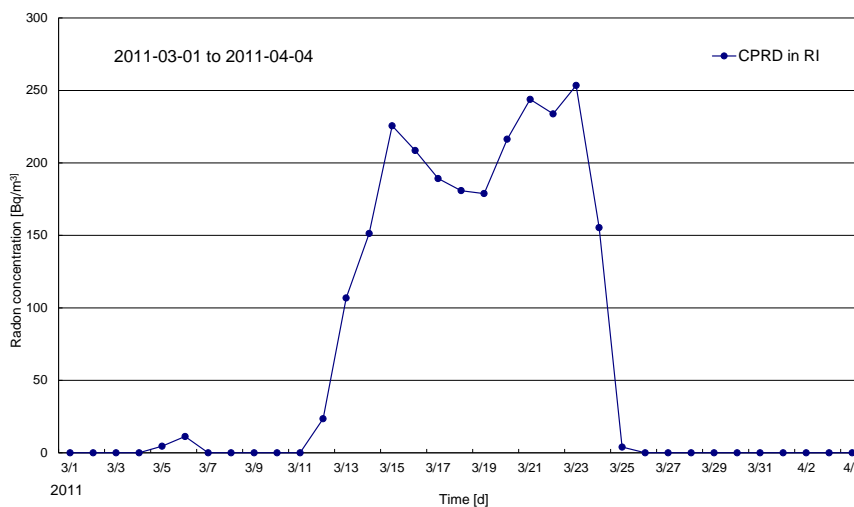


Figure 2. Change of atmospheric radon concentration after the magnitude 9.0 earthquake in a room of the Radioisotope Center.

## 4. Discussion

From the early stage of the increase of gamma-ray background caused by the crisis in Fukushima Daiichi nuclear power plant, the author distributed the data of Figure 1 to the relevant people within the campus almost every day, to confirm that there was no another accident in the nuclear power plant. Frequency of the data distribution became roughly once a month nowadays. The audience of the emission of this information asked the author several questions.

How could we translate “cps” in Figure 1 to “micro sievert per hour”? This was a serious but quite difficult problem. The author had no high precision dosimeters for environmental level measurement. Only a pocket dosimeter (Panasonic, ZP-145) was placed in my office on the 18th of March, and comparing cps of NaI with this dosimeter, a conversion factor of  $9.4 \times 10^{-4}$  ( $\mu\text{Sv/h}$ )/cps was temporarily obtained. The author intends to get more precise dosimeter.

The reason of long half-life is really the influence of supplies from nuclear reactor? Concerning this question, there is a very interesting report by Meteorological Research Institute<sup>4</sup>. This report says that the fallout of Cs-137 away from the Chernobyl nuclear disaster faded environmentally with the half-life of 25 days. Thus, the present author guessed that the newly supplied radioisotopes from Fukushima Daiichi Nuclear Power Station might be the origin of the half-life longer than 100 days

Is the expression with half-life really appropriate for the time change of cps? The answer is not so clear either. However, radioisotopes from nuclear power plant are divided into two groups, i.e., with short half-life one (I-131) and with long half-life ones (Cs-134, Cs-137 and Sr-90). Therefore, the idea of the sum of two groups of RI with different half-life may be one of the simplest models, at the present time of three months or 100 days after the accident.

## 5. Conclusions

Natural radiations revealed various responses from the nuclear power plant accident. For the gamma radiation data, a non-linear least squares fit indicated short and long half-life decay of the radiation. Shorter half-life is clearly recognized as the contribution of Iodine 131, while longer half-life and its continuation to be longer and longer may be attributed to the fact that the emission of radioisotopes from the nuclear power plants are still in progress.

## References

1. Kobayashi T. Indoor-atmospheric radon-related radioactivity affected by a change of ventilation strategy. Fukushima Journal of Medical Science 2006; 52: 59-64.
2. Mathematical Systems, INC, <http://www.msi.co.jp/splus/>
3. The R Project for statistical Computing, <http://www.r-project.org/>, <http://www.okada.jp.org/RWiki/>
4. “Artificial Radionuclides in the Environment” series articles, [http://www.mri-jma.go.jp/Dep/ge/2007Artifi\\_Radio\\_report/Chapter5.htm](http://www.mri-jma.go.jp/Dep/ge/2007Artifi_Radio_report/Chapter5.htm)