Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

AAS24-P01 Room:Convention Hall Time:May 20 18:15-19:30

Depositions of radioactive dust in the atmosphere

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Introduction:

A monitoring post around the nuclear power plant measured ambient dose rate and rainfall until March 16, 16:44 under no power supply. The records were recovered at July 20, 2012; where, movements of radioactive isotopes in the environment, i.e., decay of the sedimentation and the energy spectrum is stored. By analyzing meanings of the records, and constructing models to simulate radioactive environment; it is an effective way to approach the truth of accident.

Theory:

The ambient dose rate is detections of radiations from grounds and sky with no-separation of the source. We try to separate them under following suppositions;

1. There are time zones that are negligible radioactive substance in the atmosphere.
2. The decay expressions in the environment can be determined for the period exactly.
3. There are observations for the rainfall in the period.

We believe in the suppositions are enable near the nuclear power plant.

We determine deposition-ratio under the conditions at first, and by using the ratio and an iterative sedimentation-equation. We separate ambient dose rate into 2 parts for ground and space. We write the deposition equation;

$Bk(t+1)=\exp\{A(t+1)\}/\exp\{A(t)\}[Bk(t)+\{Dose(t)-Bk(t)-Bg)\}Dp]$, (1)

This is an iteration that is, Dose(t) is observed ambient dose-rate. Bk(t) is dose rate on the ground for a target plume. Bg is back-ground dose-rate caused by pre-deposition step, usually it is a constant.

Dp is a parameter, and deposition-rate, which is determined in the iteration (1).

To solve the iteration, you define a target plume, and set the start and terminal time. We write them as t_start and t_end.

Two equations,

$Bk(t\_start)=Dose(t\_start)$, $Bk(t\_end)=Dose(t\_end)$, (2)

are restrictions to determine the Dp.

The decay function A(t) is determined from observations of the ambient dose rate after t_end time.

We select an experimental function,

$\exp(At2+Bt+C)$, $abs(A)<<abs(B)$, $A>0$, $B<0$. (3)

The determination constant R2 is required over 0.999.

Thus; we get an approximate ground dose rate function, {Bk(t)}, $t\_start<t<t\_end$, and Dp parameter.

We apply the approach to 4 plumes on Ohno point, {37.41N, 140.98E}. The sampling rate is 2 min.

And, we get, deposition coefficients are 1/109, 1/280˜1/195, 1/21.4 for dry, rain-detection, 0.5mm-rain. Figures and details are listed in URL of reference [1].

Apprication:

Using them, as a kind of the inverse problem, we simulate the radioactive contamination in Nakadori district in Fukushima. Outline is;

1. simulated time: 3/15, 0h˜3/16, 23h.
2. The atmospheric layer is 10, the maximum is 529m.
3. On each layer, the sedimentation (Sk) is fall to the ground. Relations between Sk and rainfall are;

$Sk=D*Radi*(r+0.1)**0.79$, $D=1/280$ (i.e., drizzle case at Ohno point), the exponent 0.79 is quoted from reference [2]. Bias 0.1 is a fitting parameter. The variable r is,

$r=6000*r\_org$ (r_org is RAW data of rain simulation).

Radi is a tracer-density, simulated as Cs-137. So, the ground sedimentation is got from 10 layer sum of Sks.

Thus, we get simulated dose rates for Fukushima, Koriyama, Shirakawa, Tamura-Funehiki cities,
2.93, 0.96, 1.73, 1.12 micro Sv/h. Observed ones are 2.92, 0.98, 1.41, 1.03, respectively.

Results:
We determine deposition ratio in case of rain, based on the ambient dose rate.
We simulate intensity of radioactive dose rate on Nakadori in Fukushima prefecture at the time that short-term radioisotopes are negligible and radiations from the ground become stable. It is after 15 hours from the first sedimentation. The simulations are reasonable.

Reference:
[1] Analysis of Ohno-point in Fukushima: OhnoPoint.doc
in http://suspendedparticulatematter.web.fc2.com/
[2] B. Sportisse, A review of parameterizations for modelling dry deposition and scavenging of radionuclides, Atmospheric Environment 41(2007), pp. 2683-2698.

Keywords: radioactive SPM, deposition, ambient dose rate

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Evaluation of fluctuation in the concentrations of radioactive aerosols as a stochastic process

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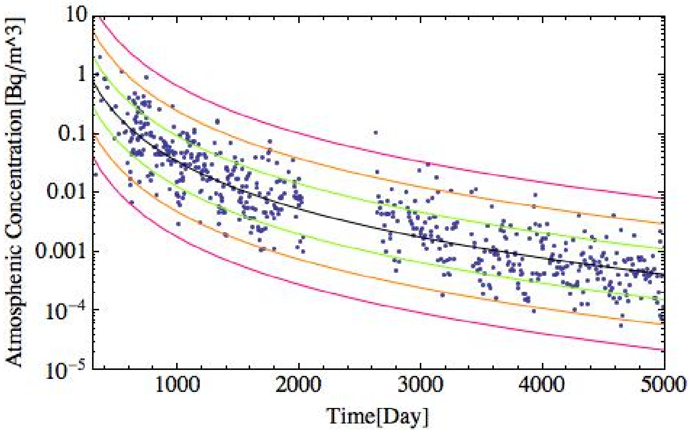
It is an important task to estimate the future state of the polluted site near the Fukushima plant. The major method for predicting the future concentration of radioactive aerosols is, as well known, the computer simulations that are based on the numerical fluid dynamics. Those simulations are an effective and powerful, but we propose a different approach. In the present study we deal with a phenomenological model that considers stochastic processes.

At the Fukushima accident, a lot of radionuclides have released into the atmosphere. The diffusion process of such nuclides is complicated and is not described in the usual diffusion equation. Furthermore, the measured aerosol concentration varies a lot day by day, depending on the meteorological condition. On a day of high concentration, the risk, especially the internal exposure risk, becomes large.

This research aims at developing a new model that can evaluate the magnitude of fluctuations in the concentration of radioactive aerosols. In our previous studies, we derived a formula C(t) ˜ exp(-at) tˆ(-b) which reproduce the long-term, averaged concentration of aerosols. In the present study, we make a model to reproduce the day-by-day fluctuations and thereby evaluate the deviations from the averaged behavior.

We assume that the logarithm of the day-by-day concentration changes as the Brownian motion. We found that the log-concentration can be well approximated by the Ornstein-Uhlenbeck process, one of the stochastic processes. We solved a stochastic differential equation of the process and obtained the analytical solution.The solution shows that the increments between observations follow the log-normal distribution. Both the mean and the variance of the distribution do not depend on time; both of them serve as fixed values. Finally, we make a figure (below) in which the long-term concentrations together with the range of their fluctuations every standard deviation.

Keywords: predicting the future, fluctuations in the concentration of radioactive aerosols, stochastic processes, Ornstein-Uhlenbeck process, log-normal distribution



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Long term and wide prediction of radioactive diffusion by means of levy flight model

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We applied the Levy-flight model for estimating the special distribution of surface radioactivity in Fukushima. The reason why we use the Levy-flight model is that the data, measured in the 50 km vicinity of Chernobyl, follow the model.

We analyze the data of Chernobyl and found that the surface concentration of a specific radionuclide, such as Cs-137, decreases with the power law (that is one of the characteristics of the Levy-flight model) as the distance from the hypocenter increases. Of course, the surface concentration should be strongly site-specific, depending on many conditions, especially geomorphological or meteorological. However, we would think that it is still useful to make a rough estimate of the spatial distribution of the pollution.

The Levy-flight model is one of the stochastic models. A Levy flight is a random walk in which the step-lengths have a certain probability distribution that is fat-tailed. In the present study we use the power function as the probability distribution. In the two-dimensional space, the steps made are in isotropic random directions. The trajectories of Levy flight are a mix of long and short trajectories. The difference of this model from the ordinary Brownian motion is that the Levy flight produces extremely long trajectories sometimes. Such kind of randomness can be found in turbulent fluids. It is also known that the Levy flight is related with the fractal science. Some studies show that a fractional-differential equation corresponds to the density of particles which are doing Levy flights.

In the following, we explain how we apply the Levy-flight model to the surface radioactivity. We assume that the radionuclides, which had been deposited on the ground, spread mainly by wind. According to the studies about resuspension, it is known that resuspension occurs when the wind velocity is larger than a threshold value. If the wind velocity is below the threshold, radionuclides are not suspended in the air and do not move. We regard the movements of suspended nuclides as the long flights of Levy flights, because the radionuclides are carried for a long distance during suspension. Immobile nuclides are regarded as short Levy flights. Artificial disturbances such as agriculture or traffic should be affect significantly to the movement of radionuclides. However, we assume them negligible, since we deal with a wide-range behavior of radionuclies in this study. In wide region such as 30 km, artificial disturbances may be small enough, compared with natural winds that blows all over the region, and all time.

The procedure of our calculation is as follows. We define the parameters of Levy flights, using the measured data of Chernobyl. The probability of existence of a particle of the Levy flight corresponds to the surface concentration. Then we calculate the special- and temporal evolution of the concentration by means of solving numerically a fractional-differential equation. Following Grunwalt-Letnikov formula, we use the software Mathematica and obtained the special distribution of the surface concentration.

Keywords: radionuclide, Levy flight, Fukushima, Chernobyl, simulation

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Radioactivity measurements for air-dust samples around Fukushima prefecture

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We have been collecting air-dust using high volume air sampler at Fukushima city (Fukushima Pref.), Marumori town (Miyagi Pref.) and Hitachi city (Ibaraki Pref.) since the accident. We identified the radioactivities of 134Cs and 137Cs in filters using high purity germanium detector. We also identified 7Be activity to monitor meteorological condition. The activity ratio of 134Cs /137Cs was mostly constant, on the other hand, the absolute activity of 134Cs and 137Cs varied with sample collection date by about ten times. In this report, we discuss the relationship between the time variation of the radioactivity concentrations and meteorological phenomenon.

Keywords: Air dust, Radioactivity, Radioactivity measurement