

Radioactive Dust in the Air

by

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Abstract

After various kinds of the dust collector were inspected and compared in order to observe radioactivity in the air, the electric dust collector was proved effective for the purpose.

Natural radioactivity in the air averages some 10^{-16}C cm^{-3} , which is mostly due to Radon daughter and Thoron daughter. The relation between suction time and saturated time of natural radioactivity was studied.

Also is reported the diurnal variation of artificial radioactivity in the air from November 1954 to March 1956. Its activity reached some $10^{-7}\mu\text{C/l}$ at maximum.

1. Introduction

Since the H-bomb test at the Bikini Atoll in the spring of 1954, to investigate the atmospheric contamination has become necessary not only from the viewpoint of meteorology but also from environmental sanitation.

In this paper the authors report on the result of the observation from November 1954 to March 1956 and its method of measurement.

2. Method of measurement

There are two methods of investigating the atmospheric contamination; 1) to measure the radioactivity of rain water, which has been generally used, 2) to measure the radioactivity of the dust in the air [1], [2].

In the first method rain drops capture radioactive dust efficiently, but meteorological conditions are influential, and, above all, no samples can be obtained without rain. In the second, samples are obtained constantly under the same condition, while collection efficiency is not so good.

In the last method of collecting atmospheric dust, various dust collectors are available: Impinger, Cascade impactor, Thermal precipitator, Filter paper dust sampler, Electric precipitator, etc. The Electric precipitator was employed in our observation for such reasons as will be presented in the following section.

There are two types of Electric precipitator: A-C precipitator and Electrostatic precipitator. The collection rate of those precipitators are almost the same [2].

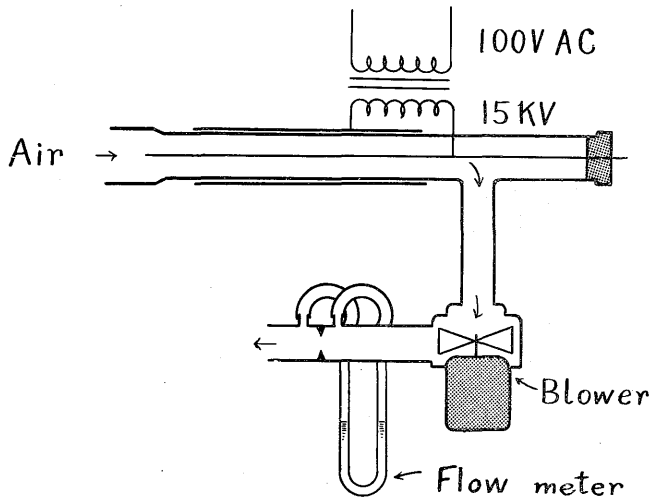


Fig. 1. The electric precipitator.

In the observation the A-C type was mostly employed. As shown in Fig. 1, it is the same type as designed by P. DRINKER [1], composed of three parts; power supply, precipitation tube, and suction equipment.

The power supply is served with 15,000 volts through the luminous tube transformer from A-C lighting current. The precipitation tube is the T-type one made of pyrex glass 3 cm in diameter and 0.1 cm thick. An

inner electrode is a platinum wire of 0.03 cm in diameter stretching through the center of glass, and the other electrode is covered with 12 mesh copper screen wrapped tightly around the glass tube.

The blower of 40 litres per minute is used to suck the air in. The flux of air can be read at the water level in a U-tube flow-meter.

The Electrostatic precipitator is supplied with 10,000 to 15,000 volts through the radioamplifier (140 KC) from 100 volts A-C line [2].

The inlet is installed 2 meters above the ground and the air is sucked in 5 hours or so per day, some 10 cubic meters in suction volume. The dust which has attached to the inner wall of the precipitation tube is washed in water and further washed off in a beaker with a rubber-tipped glass bar. The following procedures are the same as in the case of rain water.

The samples are measured more than 24 hours after collection to avoid the influences of the natural radioactive substances.

Each sample is measured by Kaken Model-32 or Decatron beta counter. 1 cm is the distance between mica window and the sample.

3. Collection efficiency of the radioactive dust

Before discussing about the dust collector, the relation between radioactivity in rain drops and the atmospheric dust shall be taken up for consideration. It has been already known that rain drops capture radioactive dust in the air. The decrease of the dust particles in the air caused by rain water will be expressed in the following formula [3]:

$$(1) \quad N = N_0 e^{-\frac{3ER}{4r}}$$

Here, N_0 indicates the number of the dust particles which are initially contained in the air, E collection rate, r radius of a rain drop and R precipitation amount.

Indicating the average radioactivity of the dust particle as \bar{A} , the radioactivity of the dust in the air A_a is written as follows:

$$(2) \quad A_a = \bar{A} N_0 e^{-\frac{3ER}{4r}}.$$

On the contrary, radioactivity of rain water will increase the amount of precipitation. This relation is expressed in the following.

$$(3) \quad A_R = H \cdot \bar{A} (N_0 - N) = H \cdot \bar{A} \cdot N_0 (1 - e^{-\frac{3ER}{4r}}).$$

In this formula A_R indicates total radioactivity in case of rain-fall R , and H the generating level of rain. The formula (3) shows with good satisfaction the radioactivity of rain water [4], [5]. It means that the number of Aerosol particles reduces by half with 0.46 mm rain fall in case an Aerosol particle is 8μ in radius, a rain drop is 0.4 mm in radius, and collection efficiency is 0.8 [3]. From the above-mentioned, it is known that rain will capture radioactive dust with high efficiency.

In case of collecting dust in the air with the dust collector, the flux of the air and collection efficiency for Aerosol particles are the first consideration. The collection efficiency of the Thermal precipitator is nearly 100% for particles smaller than 10^{-4} cm in radius, but the flux is very small. And the Impinger, the Impacter and the Filter paper dust collector would increase the flux of air, but their collection efficiency for particles smaller than 10^{-4} cm decreases. On the contrary, the Electric precipitator is favoured with the advantages as regards these conditions and so it was employed finally.

Table 1. The comparison of Electric precipitator with Impinger at CMO, 1954.

Date	Instrument	Suction hours		Suction volume	Back-ground	Net counting rate	Count per $10m^3$
		Time	Hour	m^3	c.p.m.	c.p.m.	c.p.m.
12. 10	Electric precipitator (E)	0700—1200	5.0	12.0	21.2	21.3	17.5
	Impinger (I)	0700—1200	5.0	12.3	22.7	1.9	1.5
12. 11	(E)	0700—1140	4.7	9.7	20.8	12.3	12.7
	(I)	0700—1200	5.0	12.3	20.8	0.3	0.2
12. 13	(E)	0750—1200	4.2	10.1	19.8	30.9	30.6
	(I)	0750—1200	4.2	10.3	19.8	1.3	1.3

Concerning the size of radioactive dust particles and the distribution of radioactivity, there are some data on natural radioactivity obtained by WILKENING [6]. Separating the particles by their mobility and measuring their individual activity, he reports that the greater parts are distributed into the particles of 0.001 to 0.04μ in radius.

Considering that the collection efficiency of radioactive substance by the Electric precipitator is as much as ten times that of the Impactor or the Filter paper, it is understood that the greater parts of radioactive substance attach to such minute particles.

4. Natural radioactivity of the sample

In radioactivity immediately after the collection of the samples, the decay of natural radioactivity is recognized. As given in Fig. 2 and Fig. 3, it is due to Radon and Thoron daughters contained in the air. Half-life is some 30 minutes and 11 hours respectively. The average of this radioactivity is nearly 10^{-16} C cm⁻³.

The decay 4 to 5 hours after the collection is given in Fig. 2. Apparent half-life is 39.6 minutes on an average of 19 observations. The deflection of the decay curve is seen always 2 to 3 hours after the collection of the sample.

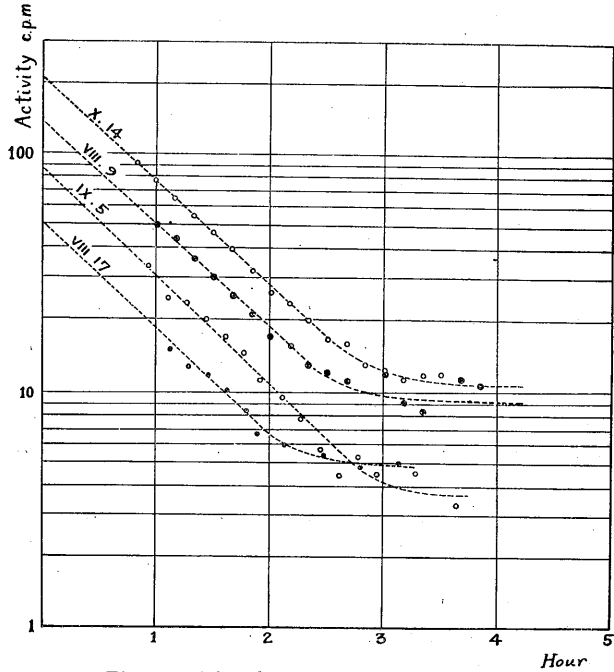


Fig. 2. The decay curve 3 or 4 hours after the collection.

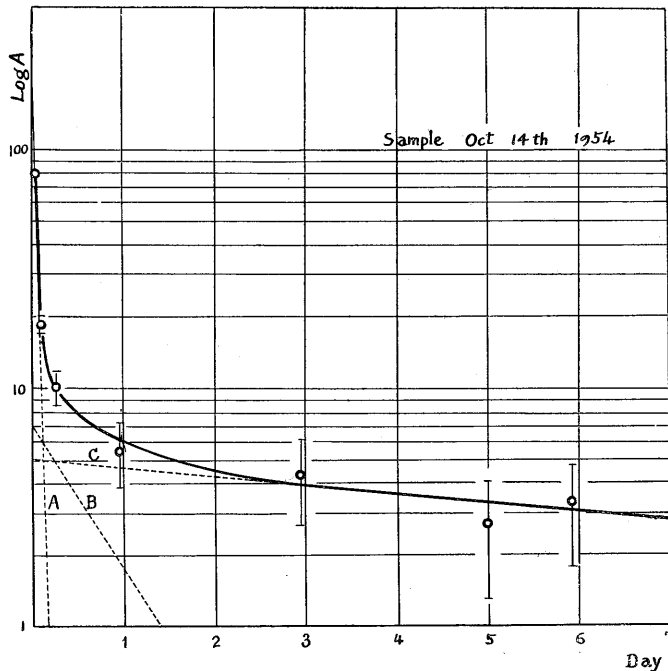


Fig. 3. The decay curve during a week after the collection. A: the decay of $r_a(B+C)$; B: the decay of ThB ; C: the decay of fission product.

The appearance of the decay is mostly due to the influences by Radium B and Radium C.

Fig. 3 shows the decay curve during the week after collection and that is an example in which Thorium B is recognized [7]. After the disappearance of Thorium B radioactivity, that of the fission product only remained. The decay of fission product indicates the function of time after the detonation.

In collecting the radioactive dust it must be paid consideration that radioactivity reaches the saturated state with the prolongation of suction time on account of short half-life. This relation is expressed:

$$\frac{dN}{dt} = VC - N\lambda \rightarrow 0,$$

where, N the number of atom on the collecting tube λ disintegration constant, V suction velocity, C Atomic concentration of the air.

5. Diurnal variation of the artificial radioactivity

Fig. 4 shows the measured value of artificial radioactivity of the dust in the air from November 1954 to March 1956.

During the period the peaks were seen four times; November 4~10, 1954,

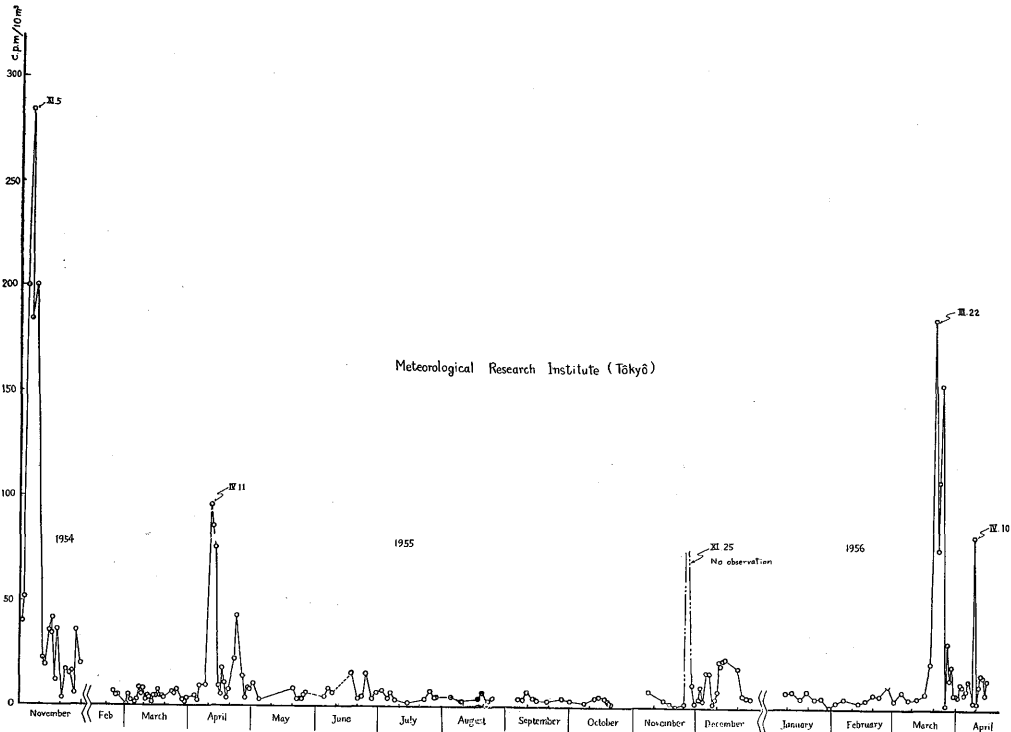


Fig. 4. The measured value of artificial radioactivity of the dust in the air November 1954 to March 1956.

April 11, 1955, November 25, 1955 and March 22, 1956.

Presumptions on these detonations are shown in Table 2.

Table 2. The presumption on the detonation from November 1954 to March 1956.

Observation date	Presumption of detonation date	Detonation spot	Maximum activity
Nov. 4~10, 1954	Oct. 31, 1954	North West of Japan	$1.2 \times 10^{-7} \mu\text{c/l}$
Apr. 11~13, 1955	Mar. 29, 1955	Nevada, U.S.A.*	$4.3 \times 10^{-8} \mu\text{c/l}$
Nov. 25~28, 1955	Nov. 22, 1955	Near L. Baikal, USSR**	(not observed)
Mar. 22~25, 1956	Mar. 13~15, 1956	Unknown	$1.0 \times 10^{-7} \mu\text{c/l}$

* Official announcement of A.E.C., U.S.A.

** Presumption from abnormal barographic oscillation in Japan.

Concerning the observation date, March 22, 1956, the presumptive method of the detonation date is shown in Figs. 5 and 6, because the decay curve of fission product is expressed in the following formula :

$$A = A_0 t^{-a}$$

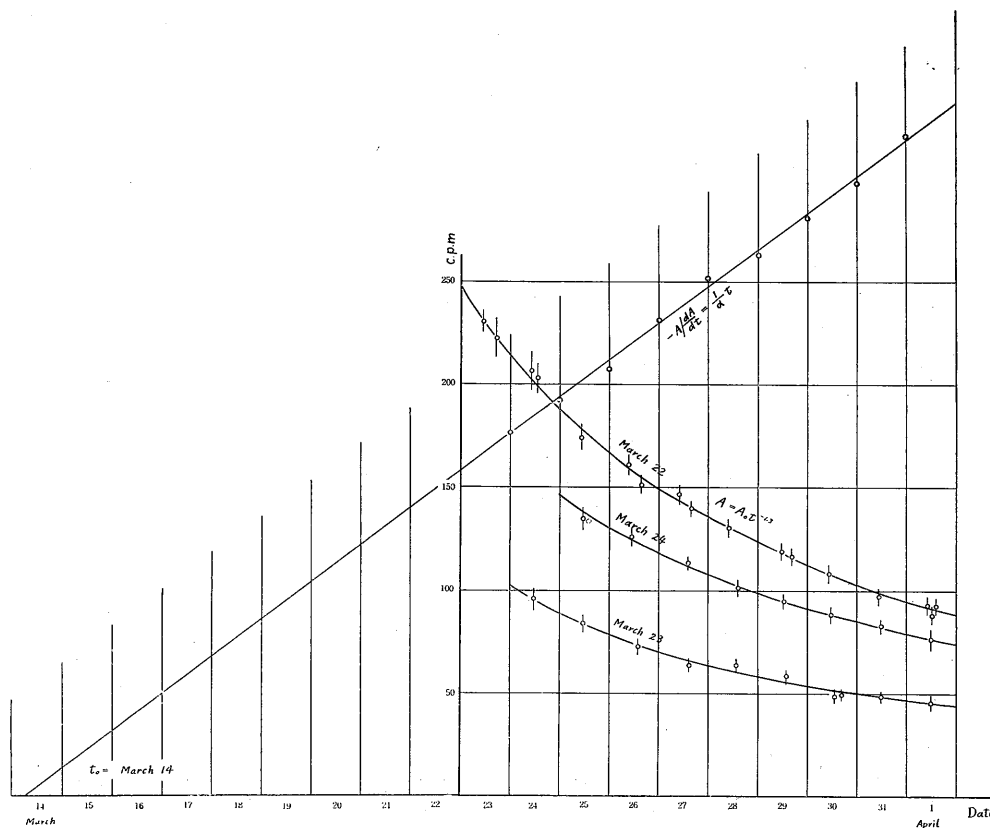


Fig. 5. The presumptive method of the detonation date.

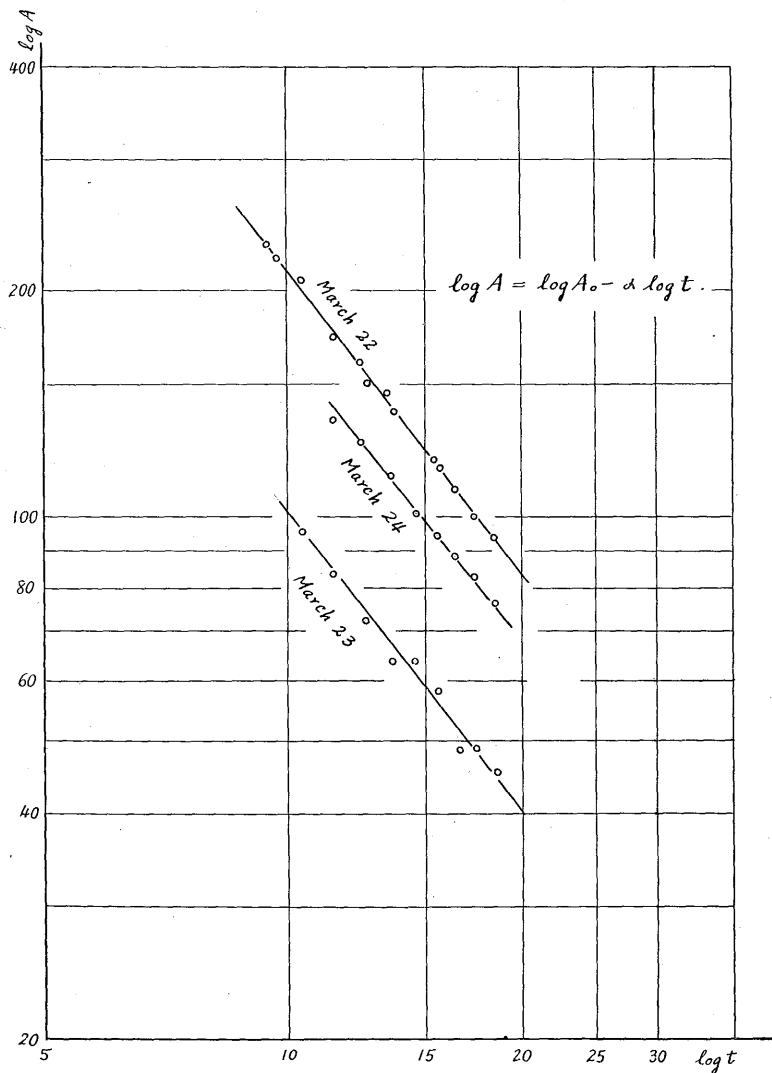


Fig. 6. The presumption method of the detonation date.

$$(4) \quad A \left/ \frac{dA}{dt} = \frac{A_0 t^{-\alpha}}{-\alpha A_0 t^{-\alpha-1}} = -\frac{1}{\alpha} t, \right.$$

$$(5) \quad \log A = \log A_0 - \alpha \log t,$$

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