JAERI 1081

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Radiological Monitoring Point

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Radiological Monitoring Point
—Photographic Dosimeter and Gammed Paper Station—

Summary

Descriptions are made of the "radiological monitoring point", a simple and economical environmental monitoring device, used in the vicinity of an atomic energy facility. The device consists of a photographic (and/or glass) dosimeter for cumulative radiation dose measurements, and gammed paper for measurements of the integrated concentration of particulate radioactivity in the air.

Experiments were performed on the latent image fading and growth for periods up to 12 months in order to find the possibility of using photographic dosimeters in which a badge film is used for the environmental gamma radiation measurement. It was shown that if the badge film is suitably packaged and is free from humidity and light, it may be used successfully for the environmental monitoring. In the experiments performed the errors in doses measured by the films were ± 60% at 30mR, ± 50% at 50mR and ± 30% at 100mR.

The integrated concentration of particulate radioactivity in the air can be evaluated by measuring the total deposited activity and the velocity of deposition.

The environmental radiation monitoring program with the radiological monitoring point at the Japan Atomic Energy Research Institute is also described.

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放射線モニタリング・ポイント

－Photographic dosimeter，ガムドペーパ測定点－

要　旨

原子力施設周辺の野外で使用する，簡単で経済的な１つの放射線モニタリング装置，放射線モニタリング・ポイントについて述べた。この装置は，γ 線積算線量の測定に写真乳剤線量計（ガラス線量計）を，大気塵埃放射能積算濃度の測定にガムドペーパを使用するものである。

まず，写真乳剤線量計（Badge film 使用）が環境放射線測定に使用できるか否かを知るために，１２カ月までの期間について film の潜像退行を調べた。Film を遮光し空気中あるいはアルゴンガス中で，相対湿度を０％近くにして保存した場合，潜像退行は１５％以下であった。Film を相対湿度０％近くに保ち屋外で，種々の線量率の場所で使用したとき，測定値の全体のばらつきは，３０mR で±60％，50mR で±50％，100mR で±３０％であった。

大気塵埃放射能積算濃度は，その期間の沈着放射能密度と沈着速度から求めることができる。

最後に日本原子力研究所における，放射線モニタリング・ポイントによる野外モニタリング計画について述べた。

１９６５年4月

日本原子力研究所東海研究所保健物理安全管理部

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1. INTRODUCTION

It is sometimes required to measure low cumulative radiation doses and integrated concentrations of particulate radioactive material, simply and accurately, in the vicinity of an atomic energy facility in order to make sure the works with ionizing radiation are carried on safely and in conformity the recommendations of the International Commission on Radiological Protection and with the legal requirements of national basis.

The radiological monitoring point, using a photographic (and/or glass) dosimeter for cumulative radiation dose measurements and gammed paper for measurements of the integrated concentration of particulate radioactivity in the air, is one of the economical environmental monitoring devices for the above purpose.

The photographic dosimeter, using a badge film is one of the most simple, convenient and economical instruments for the cumulative radiation dose measurement; it also provides permanent records. In the above measurement, the dose rate is usually low. This requires longer exposure periods to get sufficient dose compared with the low detection limit of photographic dosimeters, while the latent image fading and growth may not be negligible during the period. If the fading and growth are made negligibly small, the photographic dosimeter may also be used successfully for low cumulative radiation dose measurements.

The gammed paper is simple device for collecting radioactive fallout material to measure the total deposited radioactivity. If the velocity of deposition of the particles in the air is known, the integrated concentration of particulate radioactivity in the air may then be evaluated.

The present study was performed to find the possibility of using a photographic dosimeter in the environmental gamma radiation measurements and also to design a simple radiological monitoring device, consisting of a photographic dosimeter and gammed paper, for the field use.

2. PHOTOGRAPHIC DOSIMETER

2.1 Latent Image Fading and Growth

The Latent image fading and growth in nuclear emulsion during the period to the processing was found by Brush[1] as early as in 1910. The magnitude of this effect is a complex function and depends mainly on the emulsion composition and the time and condition of storage.

The mechanism of the latent image fading has been generally agreed to be primarily due to a chemical process controlled by the atmosphere, especially humidity, and to the oxygen content to a lesser extent, surrounding the emulsion, and also to the thermal effect to some extent.[2][3]

The latent image fading for the storage periods up to four months was reported by other workers[4][5], but there are no data available for longer periods of time, especially for long range environmental radiation measurements.

2.1.1 Experimental method

In order to find the possibility of using a photographic dosimeter for long range environmental radiation measurements, all films were kept under the best practically possible operating conditions up to 12 months.

Throughout the experiment, the films were grouped in two, one group in air in their container and the other in argon. The air was used to find the effect of oxygen in air, as it might be difficult to keep the films in argon with no air content, and also it is convenient if the atmospheric air influences the latent image fading very little.

The film containers also contained sufficient silica gel to maintain the relative humidity of atmosphere at approximately 0 %. The addition of water vapor greatly increases the rate of latent image fading[2].

The containers with films were kept in a room, which was air-conditioned in daytime (temperature in the room was $25\pm^{5}_{20}$ °C throughout the year). No attempt was made in the present study to determine the change in the latent image characteristics with temperature. Ziegler and Chleck[4] made experiments, using du Pont packet type 552, and they found that up to 43°C , the effect of temperature was negligible in the latent image fading of this film.

The containers with films were shielded by 5cm thick lead to avoid the background radiation until processing.

The Fuji badge film type A in type Ⅲ packet for gamma-rays was mainly tested because the Fuji badge film is used very commonly for radiation monitoring in Japan and the type A is most sensitive. All the films tested were produced in the same emulsion batch. The half of the film was coverd by 1mm thick tin.

The usual arrangement for the calibration of film with a 19.93mg Ra standard source was used for the exposure. When films were irradiated to the same expousure, they were placed under the same conditions. The variation in exposure was estimated to be less than 3 %.

After storage, they were processed simultaneously to minimize the processing error, using the Fuji Rendol, as prescribed by Fuji Photo Film Company, at 5 minutes, 20±0.5℃. The developer was not agitated during development. The photographic densities were measured by a photoelectric densitometer.

2.1.2 Experimental Results

Figures 1~4 show the changes in latent image observed for storage periods up to 12 months. Each value in the figures was obtained by avaraging the 12 readings, which were from 4 sheets of film. Each sheet of film was measured at 3 points. The other two values shown with the average are the maximum and minimum in the 12 readings.

(a) Single-irradiation

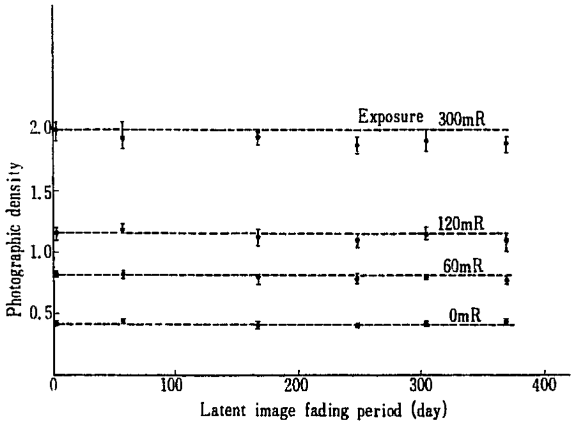
Figure 1 shows the photographic density versus the latent image fading period for "single-irradiation" of 300mR, 120mR, 60mR and no exposure. Fig. 2 shows the relative photographic density versus the latent image fading period for the same exposures. The exposure was given by the identical procedure at convenient intervals (nearly a two and half months interval) for the different films. The results showed that the stability of this film was fairly good. The no filtered films placed in dry air showed some detectable fading, as shown in Figs. 1 and 2.

The fading coefficient can be approximately given as follows:

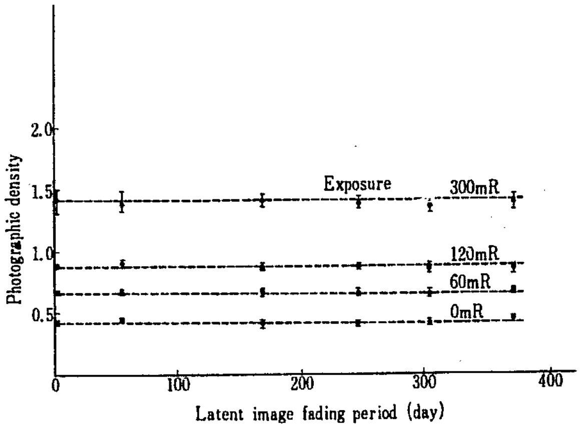
$$(D_o - D)/D_o = 1 - \mathrm{Exp}(-0.00016t)$$

where D_o is the photographic density produced by immediate development, and D is the photographic density at time t (day) after irradiation.

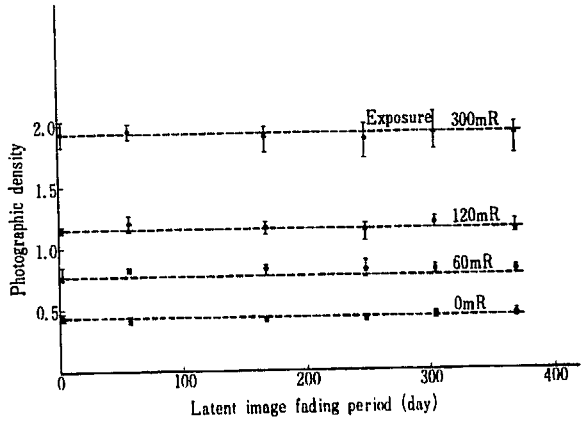
The $(D_o - D)/D_o$ is plotted in Fig. 3. The relative latent image fading and growth was less than 7 % in 12 months period.



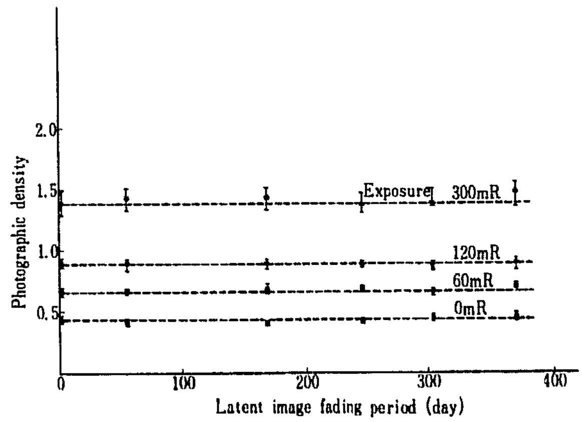
(a) Atmosphere-dry air, no filter



(b) Atmosphere-dry air, Sn 1mm filter



(c) Atmosphere-dry argon, no filter



(d) Atmosphere-dry argon, Sn 1mm filter

Fig. 1 Latent image fading of the films stored at room temperature (single-irradiation)

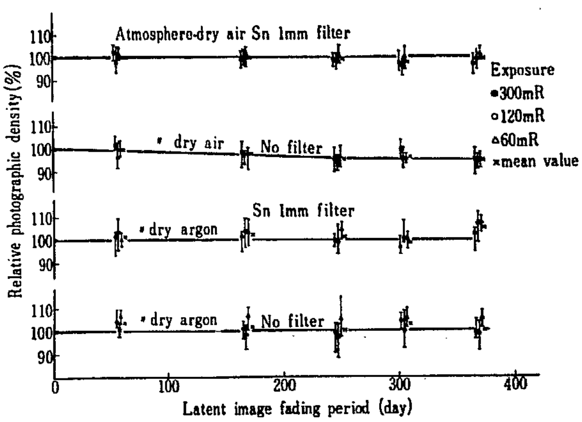


Fig. 2 Rates of latent image fading of the films stored in various conditions (single-irradiation)

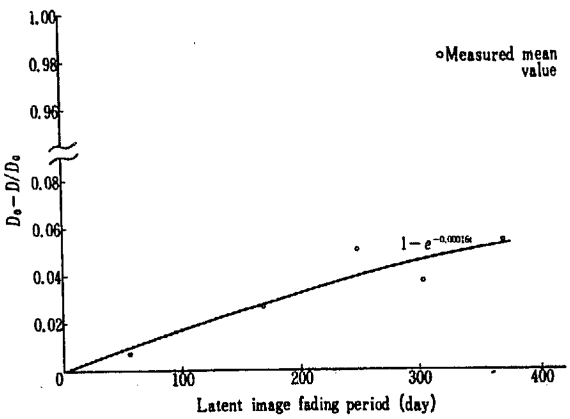
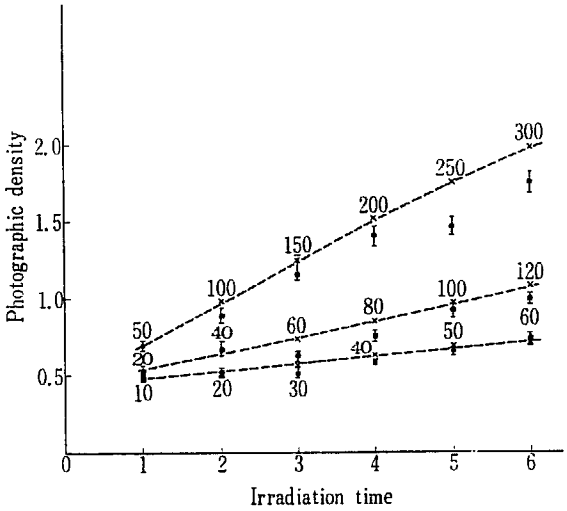
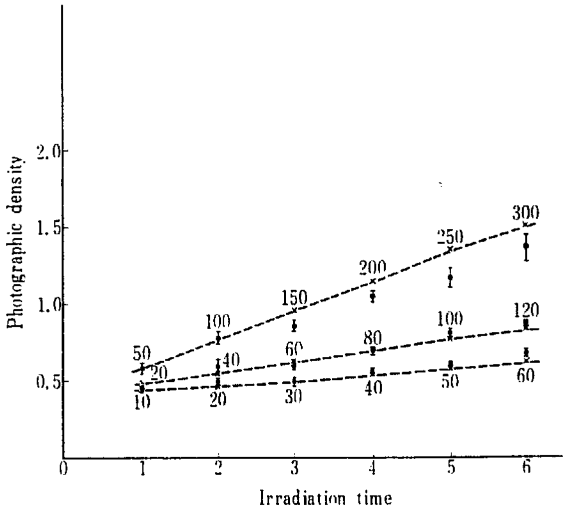


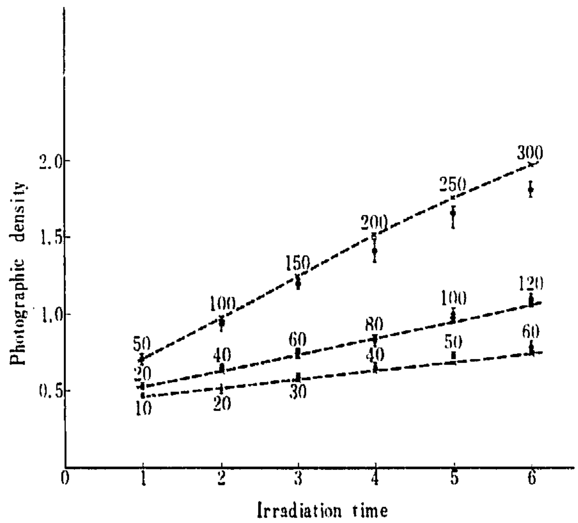
Fig. 3 Variation of latent image fading coefficient for no filtered films stored in dry air at room temperature



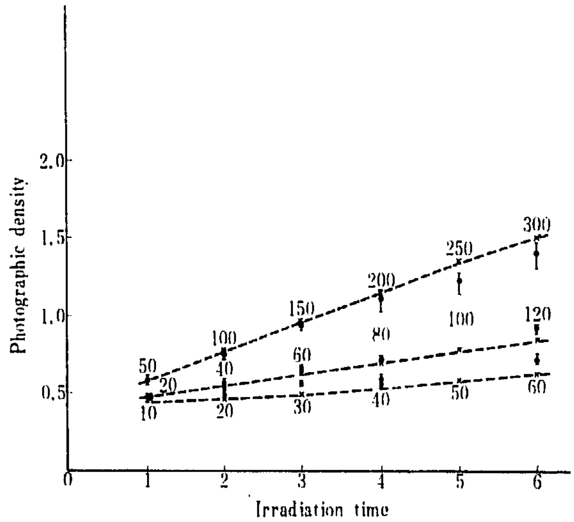
(a) Atmosphere-dry air,
no filter



(b) Atmosphere-dry air,
Sn 1mm filter



(c) Atmosphere-dry argon,
no filter



(d) Atmosphere-dry argon,
Sn 1mm filter

Fig. 4 Latent image fading of the films stored at room temperature (multi-irradiation at about 2.5 months intervals), the figures show exposure in mR

(b) Multi-irradiation

Figure 4 shows the photographic density versus the number of irradiation times for the different individual exposure of 50mR, 20mR and 10mR. The exposures were given at about two and half months intervals, instead of continuous irradiation. The broken lines show the density when developed immediately after the irradiation.

The figures show some detectable fading. The fading was somewhat less in argon than in air. The fading was less than 10 % in dry argon and 15 % in dry air in 12 months storage.

The fading was larger in the multi-irradiations than in single-irradiations. This was thought to be due to the longer periods of time for the former they were exposed to the surrounding air by multi-irradiations.

No peeling of the emulsion was observed during the experiment. As the results of an experiment at a relative humidity of nearly 0 % extending over 12 months, it was found that the latent image fading and growth of the Fuji badge film type A was less than 15 %. In this experiment, the presence of atmospheric oxygen gave a rather small effect.

The Fuji badge film type A may be used satisfactorily in measuring low cumulative radiation doses for periods of three months or more, if the badge film is well packaged and contains sufficient silica gel to minimize the humidity.

2.2 Environmental Radiation Measurements

In the environmental radiation measurements, the photographic dosimeters were kept either in a 0.5mm thick iron can or in a plastic bottle, for one, three and 12 months; in either case of containers, the film was surrounded with atmospheric air, containing enough silica gel.

These dosimeters were placed at various distances from the RI storage building. The exposure rate was measured by an ionization chamber and a side-window type Anton 106 GM counter. The value measured inside the 5cm thick lead shield was used as the background.

Figure 5 shows the exposure measured with photographic dosimeters versus the exposure measured with the ionization chamber. Each value by the photographic dosimeters was obtained by averaging the three readings at different points on the film.

No significant difference in the fading was observed for the different exposure periods. The errors in doses measured by the films were ± 60 % at 30mR, ± 50 % at 50mR and ± 30 % at 100mR. When plastic bottles were used in longer exposures in the field, there was some leak of light into the film.

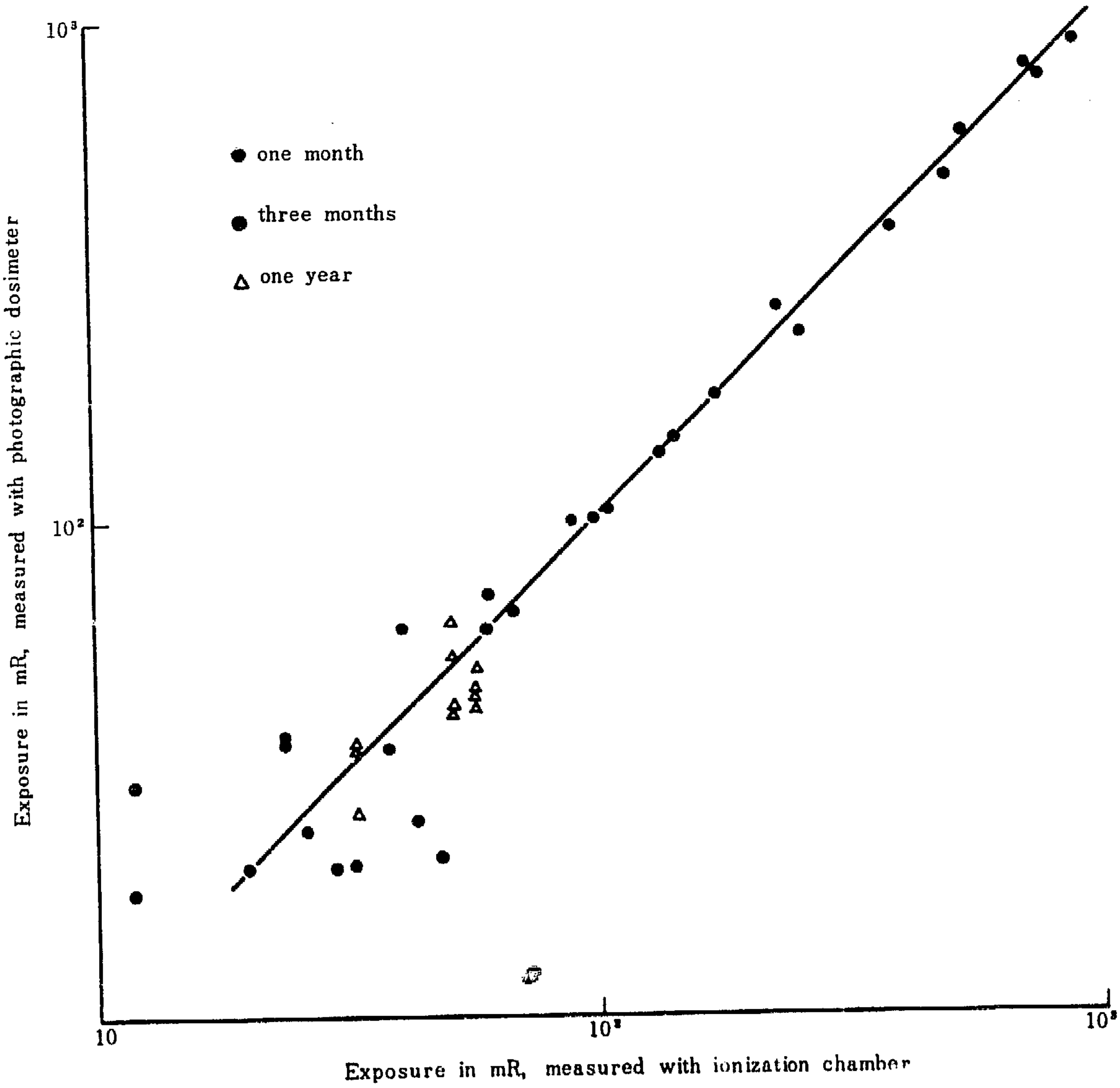


Fig. 5 Relation between the exposure measured with photographic dosimeter vs. the exposure measured with ionization chamber

Figures 6 and 7 show the photographic dosimeter, using three badge films. The three films were placed at right angle with each other to minimize the directional dependence. This resulted in more accurate measurement of the doses. The container protected the films from moisture and light and was sufficiently strong for the field uses.

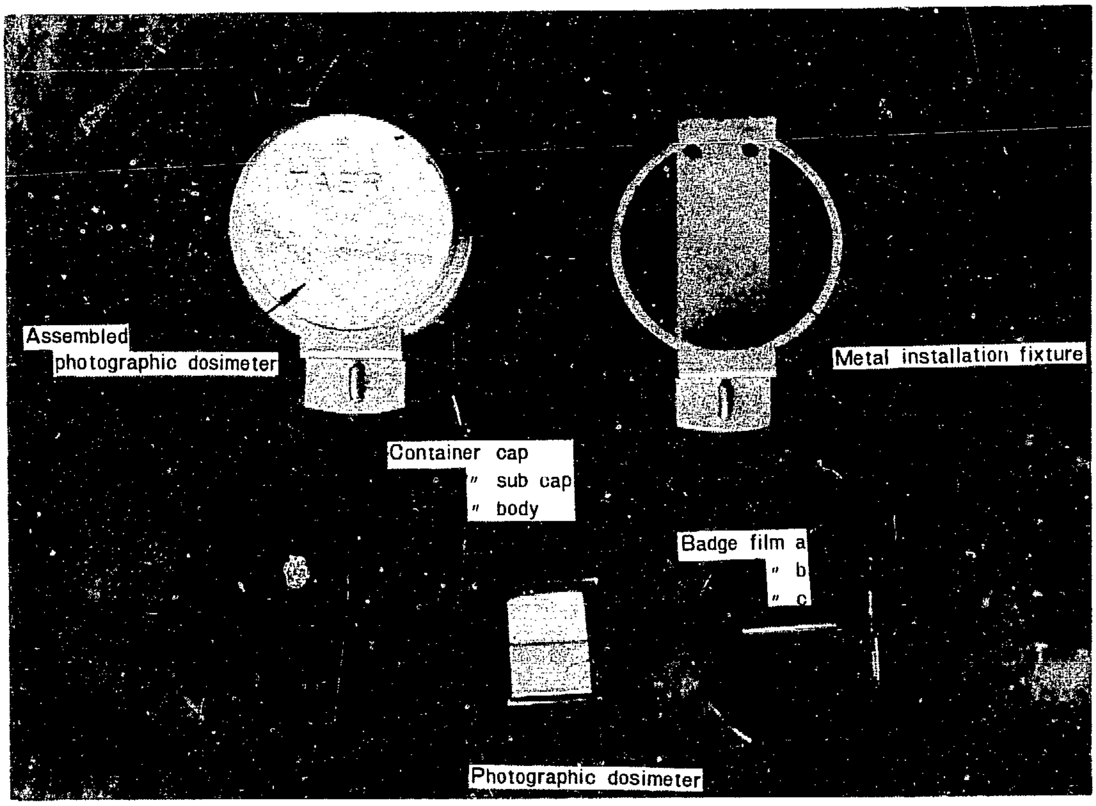


Fig. 6 Photographic dosimeter and metal installation fixture

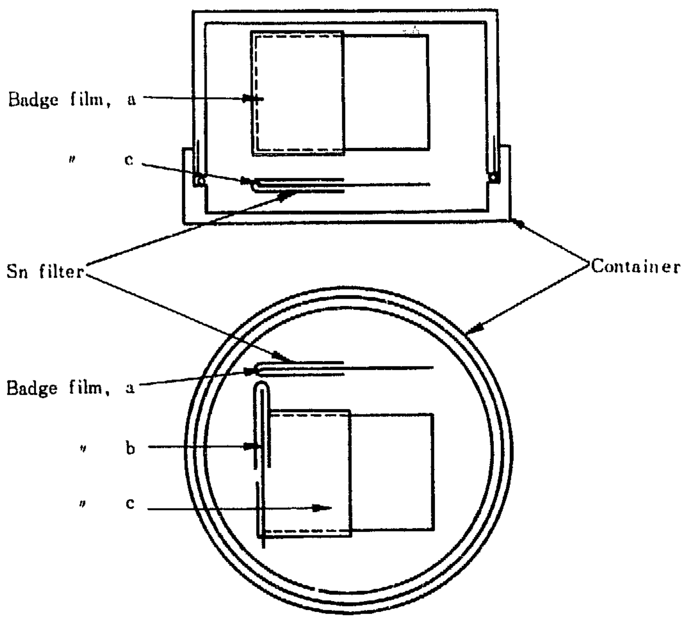


Fig. 7 Cross section of the photographic dosimeter

Figure 8 shows the directional responce of this photographic dosimeter.

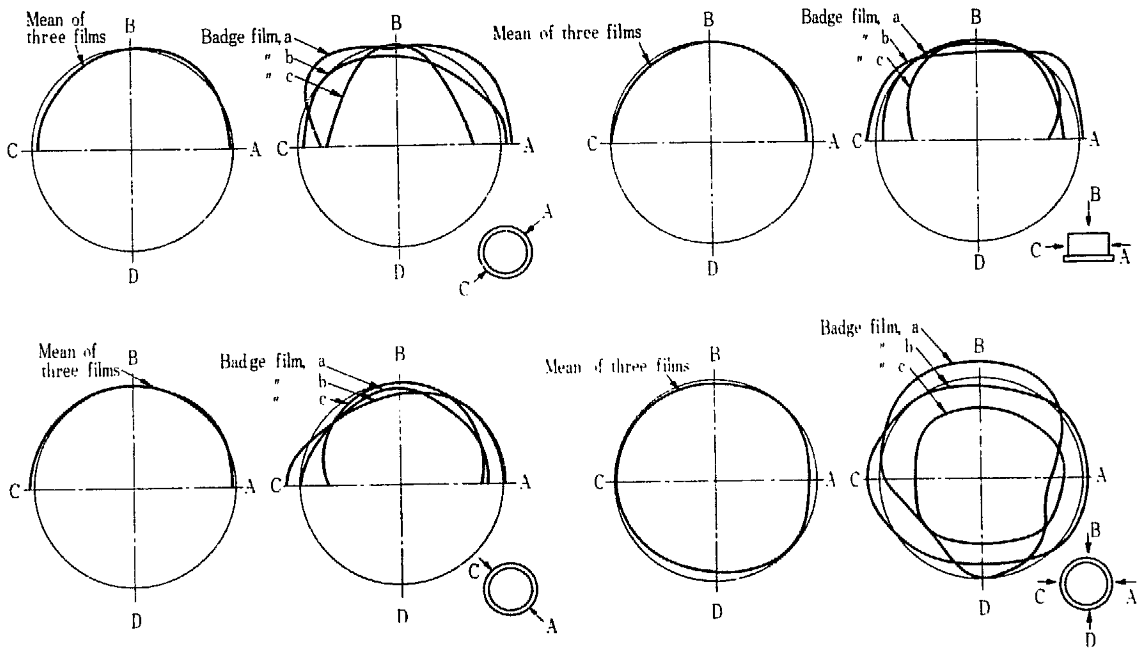


Fig. 8 Directional response of the photographic dosimeter

3. GAMMED PAPER

The gammed paper, 30 x 30 cm^2 film covered with a sticky substance, is a simple device for collecting radioactive fallout material to measure the total deposited radioactivity. If the velocity of deposition of the particles in the air is denoted by Vg, and defined by

$$V_g(cm/sec) = \frac{\text{total deposited radioactivity per unit area of ground } (\mu C/cm^2)}{\text{integrated concentration of particulate radioactivity in air} (\mu C \cdot sec/cm^3)}$$

the integrated concentration of particulate radioactivity in the air may be evaluated by measuring or assuming the total deposited activity and velocity of deposition.

The use of gammed paper for the collection of deposited radioactivity is a simple method, but some of the soluble radioisotopes may be removed from the film by rainwater and some dust particles in raindrops may be entrapped. The amount washed off is not so large as to affect the total beta count of the sample, that is not more than a few per cent[6].

4. RADIOLOGICAL MONITORING POINT

Figure 9 shows the radiological monitoring point, consisting of the photographic dosimeter and gammed paper, with the frame for the gammed paper and the meteorological shelter box for the photographic dosimeter.

The gammed paper is placed on the roof of the box about one meter above ground.

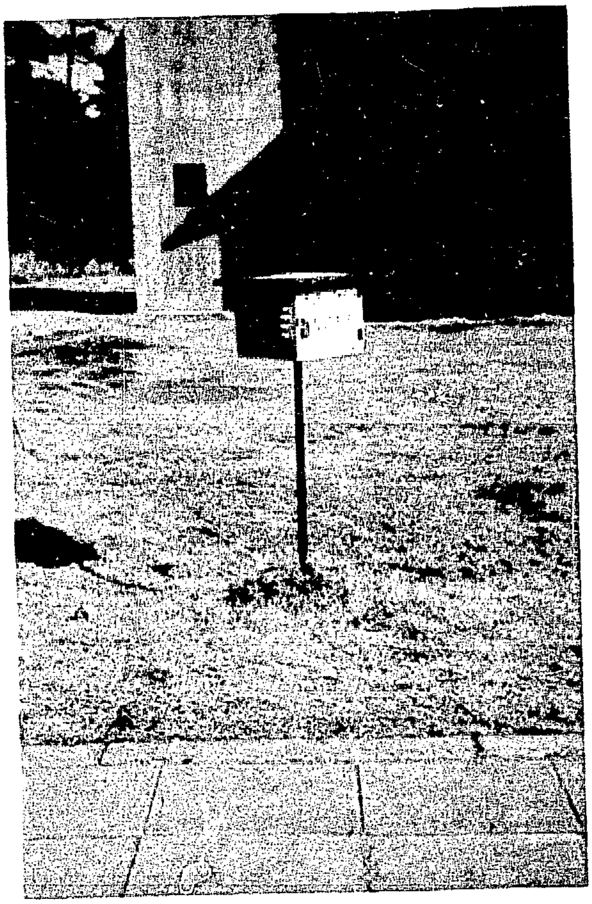


Fig. 9 Radiological monitoring point
-photographic dosimeter and gammed paper station-

4.1 Environmental Monitoring Program at JAERI

Twenty-three radiological monitoring points have been placed on and arround the site of JAERI, since April 1962 as shown in Fig. 10. The photographic dosimeters were replaced by new ones every three months.

No gammed paper was used usually as no particulate radioactivity was released in the air in their normal operations.

Arround the linear accelerator (LINAC), the JRR-1 reactor, the irradiation research buildings and the waste storage facility in the site of JAERI, the gamma radiation level was increased. The cumulative doses for the past three years have reached 100mR at the stations near the JRR-1 and LINAC buildings.

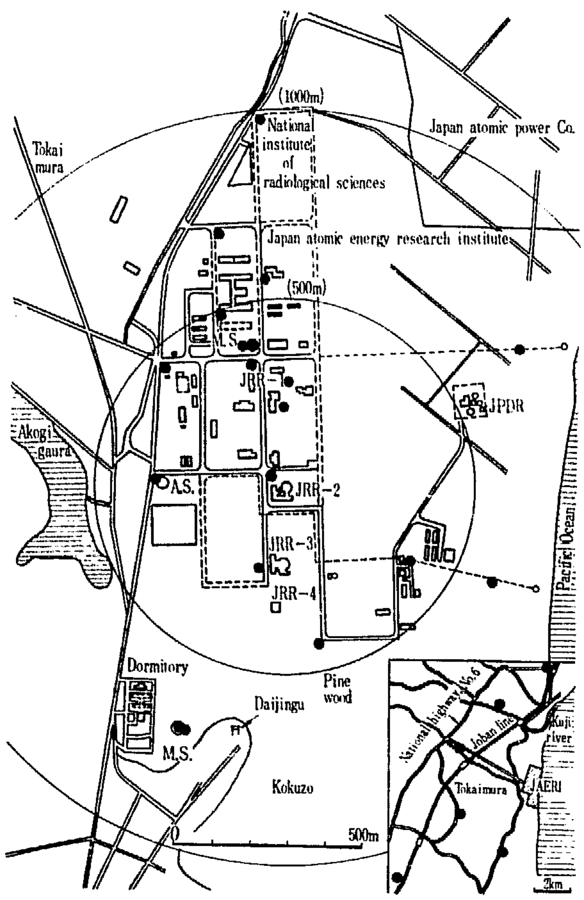


Fig. 10 Radiological monitoring points on and around the site of JAERI

●·····Radiological monitoring point

Temporary monitoring points were installed for monitoring the ^{41}A gas released from the JRR-2 reactor stack. The exposures due to the ^{41}A were less than the detection limits of the photographic dosimeter during the operation of the above reactor. The JRR-2 was operated at 10MW in October 1961, releasing ^{41}A gas at the rate of 5 Ci/hr. At that time the gamma radiation levels reaching a maximum of about 40 to 50 μR/hr were measured. But unforeseen exposures were observed from the irradiation research facility near the JRR-1. These values observed were about 300mR for one month.

With the exception of the stations which were affected by the radioactive facilities, all the measured results were some 10mR for a three months period, which corresponds to the natural environmental gamma radiation in the JAERI area. To measure such low exposures, it is necessary to increase the number of films used and to keep away the natural environmental gamma radiation from the background film, as already described.

5. CONCLUSIONS

The Fuji badge film type A may be used satisfactorily for measuring low cumulative radiation doses for periods of three months or more, if the badge film is well packaged and contains sufficient silica gel to minimize the humidity and to intercept the light.

In the experiments performed the errors in doses measured by the films were ± 60 % at 30mR, ± 50 % at 50mR and ± 30 % at 100mR.

The arrangement using three films was satisfactory to minimize the directional dependence, and also resulted in a less variation of the measurements.

In and arround the JAERI site, 23 radiological monitoring points are installed at the present, which will be increased in the future.

The use of radiological monitoring points is very simple, convenient and economical, and very useful for emergency monitoring.

ACKNOWLEDGEMENT

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