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MONITORING OF LOW LEVEL ENVIRONMENTAL GAMMA EXPOSURE BY THE CENTRALIZED RADIATION MONITORING SYSTEM

July 1981

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Monitoring of Low Level Environmental Gamma Exposure by the Centralized Radiation Monitoring System

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In the Japan Atomic Energy Research Institute (JAERI), a centralized automatic radiation monitoring system developed 20 years ago has recently been improved to monitor low level gamma radiation more accurately in normal operation of the nuclear facilities and to detect abnormal radioactive releases more effectively. The present state of the system is described.

This system puts together environmental monitoring data such as gamma exposure rate (20 points), radioactive concentration in the air (4 points) and in water (2 drains), and meteorological items (14 including wind directions, wind speeds, solar radiation and air temperatures at a observation tower of 40m height). Environmental monitoring around the JAERI site is carried out effectively using the system. Data processing system consists of a central processing unit, a magnetic disk, a magnetic tape, a line printer and a console typewriter. The data at respective monitoring points are transmitted to the central monitoring room by wireless or telephone line. All data are printed out and filed in magnetic disk and magnetic tape every 10 minutes. When the emergency levels are exceeded, however, the data are automatically output on a line printer every 2 minute.

This system can distinguish very low gamma exposure due to gaseous effluents, about 1 mR/y, from the background. Even in monthly exposures, calculated values based on the data of release amount and meteorology are in good agreement with the measured ones.

Keywords; Low Level Gamma Exposure, Environmental Monitoring, Natural Radiation, Radioactive Cloud, Annual Dose, Monitoring System, JAERI, Separation, Meteorological Data

環境放射線集中監視システムによる低レベルγ線照射線量のモニタリング

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原研の新環境監視システムは，平常運転時の低レベルγ線の管理，事故の検知と環境データの集中化，データの保守と管理の効率化等を計って設計製作されたものである。本報は，システムの構成と機能及びモニタリングポストによるγ線量の観測結果と計算値との比較について述べたものである。モニタリングポストで日常的に観測されたγ線照射線量を気象データで分類し統計的に解析した結果，1 mR／年 程度の放射性雲からの線量が自然放射線から分離評価できた。またこれらの実測評価値と安全審査等で環境γ線被曝線量評価に用いられている計算方法および環境監視システムに組み込まれている計算方法による計算評価値とを比較した結果，両方法とも実測値と良い相関を示し，これら計算による線量推定方法が日常の環境管理に効果的に活用できることが判った。

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1. INTRODUCTION

It is a matter of great importance to monitor an environmental effect effectively and continuously due to the operation of nuclear facilities from the stand point of environmental protection. According to the consideration of as low as practicable (ALAP) by the ICRP, dose objective value is recently decided in an effort to reduce the amount of radioactive materials released from the nuclear facilities. The level of dose objective value for light-water-cooled nuclear power reactors is as low as 5 mrem/year, so the estimation of this level is usually done by calculation using the meteorological conditions and the released amount of radioactive materials.

Under the above situation, JAERI has established a new computerized environmental monitoring system introducing a low-level gamma detecting technique using NaI(Tℓ)(DBM method) developed in JAERI[1] and the past 20 years experience of centralized monitoring. By centralizing the environmental informations such as meteorology elements, gamma exposures and radioactivities in the air etc., this system can monitor systematically the radiation effects upon the environment of the nuclear facilities.

The following items are discussed in the report:

① Hardware and software of the environmental monitoring system,

② Evaluation of gamma exposures due to the normal operation of the nuclear facilities using the measured values at monitoring posts,

③ Comparison of the calculated exposures using meteorological conditions and released amounts with the measured exposures.

2. ENVIRONMENTAL MONITORING SYSTEM

2.1 HARDWARE

The environmental monitoring system consists of a central observation part (computers and interfaces) and measuring parts of the environmental information. The computer system is composed of master and back up computers. The master system is equipped with a central processing unit(56kW), a magnetic disk (5 MB), a magnetic tape (800 BPI, 2400 feet), a line printer and a console typewriter. In addition to the configuration of the master system, the back up system has a card reader and other magnetic tape (800 BPI, 2400 feet) for another batch job.

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To prevent an interruption of monitoring, the central observation part of the environmental monitoring system is equipped with the following functions:

① The computer system is composed of a master and a back-up system as mentioned above. When there are failures of the central processing unit or the disk of the master system, the back-up system can detect them and take over the functions of the master system.

② Master and back-up computers are provided with a automatic restart function which operate in case of power failure. And if both the computers can not operate successfully, an alarm system informs the situation. This alarm signal as well as the radiation abnormal alarm signal are connected to the guardmen's room and in night time or holiday, the staff responsible for the system are called by the guardman to take measures.

③ The central observation part is equipped with two different lines of power supplies to minimize system failures by the power breakdown.

In the measuring parts for environmental information, there are several monitoring items including gamma exposures (measured at monitoring posts (MP) and monitoring stations (MS)), alpha and beta radioactivities in the air(MS), meteorological information, and release source information, (drain monitor, stack monitor (expected)). In Table 1, installations and methods of measurements in the environmental monitoring system are shown and in Fig.1, monitoring points of the system are shown.

Data derived from each detector and status signals of power suspension, data over flow and machine trouble are digitally transmitted over radio line (MS data of every 10 min. sampling, transmission speed of 200 BPS on the 59.81 MHz wave) or telephone data communication line (MP and drain monitor of every 30 sec. sampling and meteorological data of every 2 min. sampling, 1200 BPS).

2.2 SOFTWARE

Environmental monitoring routines are executed as shown in the flow chart of Fig.2.

30-sec routine

If high level of radiation at the monitoring posts are detected (alarm situation) by this routine, the routine sounds alarm and calls the routine of abnormal process (print out all the data collected every 2 min including the last one hour.). Data monitored every 30 sec are used for only alarm check and not stored in any recording instrument of the computer system.

2-min routine

All the 2-min data except MS are stored in the magnetic disk for 2 hrs for use of alarm situation. In case of an alarm situation, the last one hour storage of them are automatically printed out on both line printers of master and back-up system.

10-min routine

All the data are filed on magnetic tape and magnetic disk. Only gamma exposures of MP and MS and gamma concentration of drain monitor are printed out on the line printer. Data on the magnetic tape are used for various analytical purposes. Last one month data are stored on the magnetic disk and accessed for reference routinely.

Abnormal data checks such as upper limit level, lower limit level and three times of standard deviation level (3σ level) are done and outlying data found by the checks are printed out on the console typewriter.

1-hour routine

1-hour mean values of gamma exposure and gamma concentration of drain monitor are calculated from the 10 min. data and printed out on the line printer.

Using the 10 min. data of meteorological information (wind direction, wind speed and atmospheric stability), gamma exposures at MP and MS points due to radioactive cloud of the main facilities of JAERI are calculated assuming a unit release (1 MeV·Ci) and 1-hr means of their values are printed out for each facility. In case of an alarm situation, this calculation are done every 2 min.

Daily routine

Data not output on the line printer every 10 min. such as meteorological data, alpha and beta radioactivities in air and information of drain monitors are printed out as 1-hr mean values (in case of meteorology, 10 min. mean value of each hour). Statistical calculations such as daily mean value, daily standard deviation, daily maximum and minimum values and lack of data are executed and printed out for all the data collected.

Another routines (Requests)

About twenty subprograms are provided as requests for the total monitoring system to function adequately. Receiving these requests, the system can perform outputting all the data stored in the disk (monitoring data and constants used in the system) in table and figure, editing a magnetic tape and setting the constants.

3. RESULTS OF GAMMA MONITORING BY THE ENVIRONMENTAL MONITORING SYSTEM

Gamma exposures measured in the monitoring post system are statistically analyzed and the fraction contributed by the radioactive cloud released during the normal operation of reactors is separated from natural gamma exposure. Fig.3 shows gamma exposure-rate variation relating to wind direction and wind speed when 0.47 Ci/hr of ^{41}Ar is released from the 40 m-height stack of JRR-2 reactor. This example shows that the monitoring post system around the site of JAERI (see Fig.1) can effectively detect very small gamma exposure variations (less than 0.5 μR/hr).

Data at nine monitoring posts around the site were analyzed with meteorological data to estimate the net gamma exposure due to the nuclear facilities from May 1977 to April 1978. Release sources of radioactive rare gases in this period were JRR-2, JRR-3 reactors of JAERI (both research reactors of 10 MWt with 40 meter stack) and the gas cooled power reactor of Japan Atomic Power Company (166 MWe with 80 meter stack).

3.1 HANDLING OF METEOROLOGICAL DATA

Wind direction and rain data are used to select the monitoring posts influenced by the radioactive cloud with the following postulations.

① Rise of gamma exposure at monitoring posts occurs when the wind calculation are done every 2 min.

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Wind direction and rain data are used to select the monitoring posts influenced by the radioactive cloud with the following postulations.

① Rise of gamma exposure at monitoring posts occurs when the wind direction from stack to monitoring posts is within ±22.5 degree.

② Where the wind speed is less than 0.5 m/s and wind direction at given time is not defined, the wind direction is decided as same as the previously defined wind direction when wind speed is more than 0.5 m/s.

③ Rise of gamma exposure by rain begin 30 min. before the precipitation meter records the rain and end 3 hours after the rain is stopped.

④ There is no difference in the rise level of gamma exposure by rain among the nine monitoring posts around the site.

3.2 SEPARATION OF GAMMA EXPOSURE DUE TO RADIOACTIVE CLOUD

Background gamma exposure-rate data of every 10 min. not influenced by radioactive cloud and rain, are selected using the above mentioned meteorological information. By plotting the frequency distribution of the background data on the normal probability chart, mean values and standard deviations are determined daily and monthly. These mean values are subtracted from the gamma exposure-rate including the influence of radioactive cloud and rain. Flow chart of data analysis is shown in Fig.4. Monthly frequency distribution of gamma exposure-rate not influenced and influenced by radioactive cloud and rain are shown on the left-hand side of Fig.5. The right-hand side shows the method of determning mean values and standard deviations by normal probability chart. All these analyses are done by computer program. Monthly standard deviations were less than 0.15 μR/h in every monitoring post. The minimum values of daily standard deviation for all monitoring posts during all investigation period showed 0.08 μR/h. This values were observed when the detectors were not influenced by temperature variations.

As the difference of the level of gamma exposure rise by rain among the monitoring posts is found to be within 7 %, the substraction value due to rain is determined by averaging the rises of gamma exposure of upwind monitoring posts to separate the exposure due to cloud.

3.3 RESULTS OF SEPARATION

Separated net exposures are shown in Fig.6. In this figure thin solid line, dotted line and solid line show the total exposure, cloud exposure and rain exposure respectively. These separated results are summed for one year or one month to estimate the yearly or monthly exposure.

Error of estimation

The net exposure with standard deviation of ith 10 min. data for a given period is expressed by the following equation

$$n_i - n_b \pm \sqrt{\sigma_i^2 + \sigma_b^2} \approx n_i - n_b \pm \sqrt{2}\,\sigma_i \qquad (1)$$

where

n_i, σ_i : total exposure and its standard deviation of ith data ,

n_b, σ_b : background radiation and its standard deviation evaluated in 3.2 ,

$\sqrt{2}\,\sigma_i$: as the σ_i and σ_b are nearly equal, $\sqrt{\sigma_i^2 + \sigma_b^2}$ becomes $\sqrt{2}\,\sigma_i$.

For a certain monitoring post influenced n times by cloud (n is determined by meteorological information as mentioned in 3.1), net exposure is $\sum_{i=1}^{n}(n_i - n_b)$ and standard deviation is $\sqrt{\sum_{i=1}^{n} 2\sigma_i^2} = \sqrt{2n}\sigma$ (σ = 0.08 ~ 0.14 μR/hr). If the subtraction of gamma exposure due to rain is made m times, standard deviation is $\sqrt{2(n+m)}\sigma$.

Annual exposure

Table 2 shows the annual exposures from the radioactive cloud and rain measured at monitoring posts. The maximum exposure showed 1.1 mR/year at the MP-17 point (about 500 m south-west of the JRR-2 stack).

4. COMPARISON BETWEEN MEASURED AND CALCULATED VALUES OF GAMMA EXPOSURE

The above estimated monthly gamma exposures due to cloud are used for the comparison with the calculated values. Two calculation methods were compared with measured value for 4 months of Octover and September in 1977 and 1978 when only JRR-2 and JRR-3 reactors were operated.

One is the method used in this environmental monitoring system (EMS method) and the other is the method by Japan Atomic Energy Commissions guide[(2)(3)] (JAEC'S GUIDE, guide method) widely used in Japan.

4.1 CALCULATION ON THE BASIS OF JAEC'S GUIDE

The monthly dose is calculated using the monthly statistics of wind speed and wind direction by atmospheric stability class.

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4.1 CALCULATION ON THE BASIS OF JAEC'S GUIDE

The monthly dose is calculated using the monthly statistics of wind speed and wind direction by atmospheric stability class.

Equations of calculation

The ground level gamma exposure-rate due to radioactive cloud is calculated from the next equation.

$$D = K_1 \cdot E \cdot \mu_a \int_0^{\infty} \int_{-\infty}^{\infty} \int_0^{\infty} \frac{e^{-\mu r}}{4\pi r^2} B(\mu r) \chi(x',y',z') dx' \cdot dy' \cdot dz' \qquad (2)$$

$$\chi(x,y,z) = \frac{Q}{2\pi \cdot \sigma_y \cdot \sigma_z \cdot u} \cdot \exp(-y^2/2\sigma^2 y)$$
$$\times \left[\exp\{-\frac{(z-H)^2}{2\sigma_z^2}\} + \exp\{-\frac{(z+H)^2}{2\sigma_z^2}\}\right] \qquad (3)$$

where

D : exposure-rate at the calculation point (x,y,o)(μR/hr)

K_1 : constant converting activity to exposure-rate $\left(\frac{dis \cdot m^3 \cdot \mu R}{MeV \cdot Ci \cdot h}\right)$

E : primary energy of photon (MeV/dis)

μa : true linear absorption coefficient (m^{-1})

μ : total linear absorption coefficient (m^{-1})

r : distance between the receptor and a volume element of the cloud (m)

$B(\mu r)$: dose build-up factor

B(μr) is calculated from the next equation

$$B(\mu r) = 1 + \alpha(\mu r) + \beta(\mu r)^2 + \gamma(\mu r)^3$$

$\mu a, \mu, \alpha, \beta, \gamma$: value for the photon of energy 500 keV

χ : concentration of a gamma-emitter in air (Ci/m^3)

Q : release rate of the γ-emitter (Ci/sec)

u : mean wind speed at the release point (m/sec)

H : height of release point (m), corrected by the plume rise (ΔH)

$$\Delta H = 3 \frac{w}{u} \cdot D$$ (w : blow-out speed at stack outlet, m/s)
(D : diameter of stack)

σ_y, σ_z : standard deviations of the cloud in the y- and z-directions, and functions of downwind distance, x

The monthly exposure at a given point is calculated from the next equation

$$D_\gamma = D_L + D_{L-1} + D_{L+1}$$

D_γ : exposure at a given point

D_L, D_{L-1}, D_{L+1} : exposure at a given point due to radioactive clouds in downwind direction (L) and neighboring directions (L+1, L-1)

D_L, D_{L-1} and D_{L+1} are calculated from the meteorological statistics[3] obtained by following ⓐ and ⓑ

ⓐ Sum of $\frac{1}{u}$ by wind direction and atmospheric stability class

$$_wS_{d,s} = \sum_{i=1}^{N} \frac{_{d,s}\delta_i}{u_i} \tag{4}$$

where

N : number of data observed

u_i : wind speed at time i (m/s)

$_{d,s}\delta_i$: when wind direction is d and atmospheric stability is s at time i, $_{d,s}\delta_i = 1$. Except above $_{d,s}\delta_i = 0$.

ⓑ Frequency distribution of wind direction

Meteorological statistics arranged by ⓐ and ⓑ are used for the monthly exposure calculation. Results of ⓐ and ⓑ are used for the calculation of $\chi(x,y,z)$ and ΔH respectively. Equation (2) is calculated by computer code of STDOSE[4],[5]. Atomospheric stabilities are defined by solar radiation in daytime (net radiation in nighttime) and the wind speed 10 meters above ground[3].

4.2 EMS METHOD

The procedure of this calculation is shown in Fig.7. Dose rate corresponding to possible combinations of meteorological conditions and downwind distances are prepared previously using STDOSE[4][5] code. If the wind direction is given, the distances and relative angles of the downwind posts are automatically determined. The dose rate in this case can be obtained by inter- or extrapolating the dose rates prepared above.

Actually, every 10-min exposure is determined using 10-min meteorological

data, and monthly exposure can be evaluated by summing up them. Plume rise effect is not considered in this method.

4.3 RESULT OF COMPARISON

In Fig.8, the correlation of measured and calculated monthly exposure is shown. The mean ratio of these values (calculated exposure/measured exposure) obtained by averaging the ratios using only the data more than 30 μR/month was found to be 1.5 $\pm$ 0.36 based on the guide and 1.3 $\pm$ 0.17 based on the EMS method.

Therefore, the estimation by calculation is in fairly good agreement with the measurement, so that it may be effectively used for routine environmental monitoring.

5. CONCLUSION

This system which centralizes the environmental informations of meteorological elements, gamma exposures and radioactivities in air, can effectively monitor the radiation effects on the environment.

High-sensitivity gamma detectors made of NaI(Tℓ) with energy response flattened by DBM technique are successfully used for the routine monitoring of low level gamma exposures around the site. Analyzing the data of gamma exposure measured at the monitoring posts by statistical method, maximum annual exposure are estimated at 1.1 mR from radioactive cloud separated from the natural background. Further such net exposure values were used as a standard to test the values calculated by the methods of JAEC's guide and EMS. Monthly calculated exposure shows the good correlation with monthly measured exposure, but the former is 30 ~ 50 % higher than the latter. We can conclude that these calculations for the gamma cloud are effective for the routine environmental low level dose evaluation.

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REFERENCES

(1) S. MORIUCHI and I. MIYANAGA, "A Method of Pulse Height Weighting using the Discrimination Bias Modulation", Health Phys. 12, 1481 (1966)

(2) J. AEC "Guide for Methods of Evaluating Compliance with the Dose Objectives around the Site of Light-Water-Cooled Nuclear Power Reactors, (1976)(in Japanese)

(3) J. AEC "Meteorological Guide for the Safety Analysis of Power Reactor", (1977)(in Japanese)

(4) K. IMAI and T. IIJIMA, "Assessment of Gamma-Exposure due to a Radioactive Cloud Released from a Point Source", Health Phys. 17, 207 (1970)

(5) K. IMAI, T. IIJIMA and M. KAKUTA, "Graphic Aid in the Assessment of Gamma-Exposure due to a Radioactive Cloud Released from a Point Source", JAERI 1189 (1969)(in Japanese)

Table 1 INSTALLATIONS AND METHODS OF MEASUREMENT PROCESSED BY THE ENVIRONMENTAL RADIATION MONITORING SYSTEM

Monitoring items	Monitoring installations	Number of points	Detectors or measuring items	Methods of measurement
γ-exposure	Monitoring posts (MP)	14	2"ϕ×2"NaI(Tℓ). Put on the roof (2 meter above the ground).	Monitor has 2 informations, γ exposure rate obtained using the DBM* circuit and energy distribution by SCA. Corrected for contribution of cosmic-rays and radioactivity in the material of detector.
	Monitoring stations (MS)	6	Sidewindow GM tube. 1 meter above the ground	Shielded by 2mm thick brass to compensate the energy dependence. Corrected for contribution of cosmic-rays and radioactivity in the material of detector.
Radioactivity in air	Monitoring stations (MS)	6	End window GM tube for β counting and ZnS(Ag) for α counting	Measure the radioactivity on the filter which moves continuously. β and α radioactivities are measured 4hr and 8hr after sampling respectively.
Meteorology	Meteorology tower (MT) (40m-height)	1	Wind speed and wind direction, vertical temperature gradient, solar radiation, net radiation in night time, precipitation, etc.	All the analogic informations except wind and precipitation are converted to digital ones by ADC.
Liquid effluent	Drain monitors (DM)	2	γ concentration, pH, temperature water-level	Water in the drain is continuously taken to the container (1.2^mdia.×0.7^mdep., $0.8m^3$) at the rate of 0.6ℓ/h. Detector is submerged in water of the container. Drain water flow is determined from the water-level at the dam of drain pit.

* DBM Discrimination Bias Modulation for NaI(Tℓ)(ref.(1)). Output of DBM is proportional to exposure dose

Table 2 ANNUAL EXPOSURE FROM CLOUD AND RAINFALL EVALUATED ON THE BASIS OF DATA OBSERVED BY MONITORING POSTS (May, 1977~Apri., 1978)

Monitoring posts	Annual exposure (μR/year)	
	From cloud	From rain
11	229 ±1.7	419 ±1.5
12	224 ±1.6	367 ±1.3
13	411 ±2.3	409 ±1.3
15	643 ±2.4	438 ±1.2
16	856 ±2.3	434 ±1.2
17	1081 ±2.5	333 ±1.1
18	547 ±2.5	406 ±1.2
19	288 ±2.0	389 ±1.3

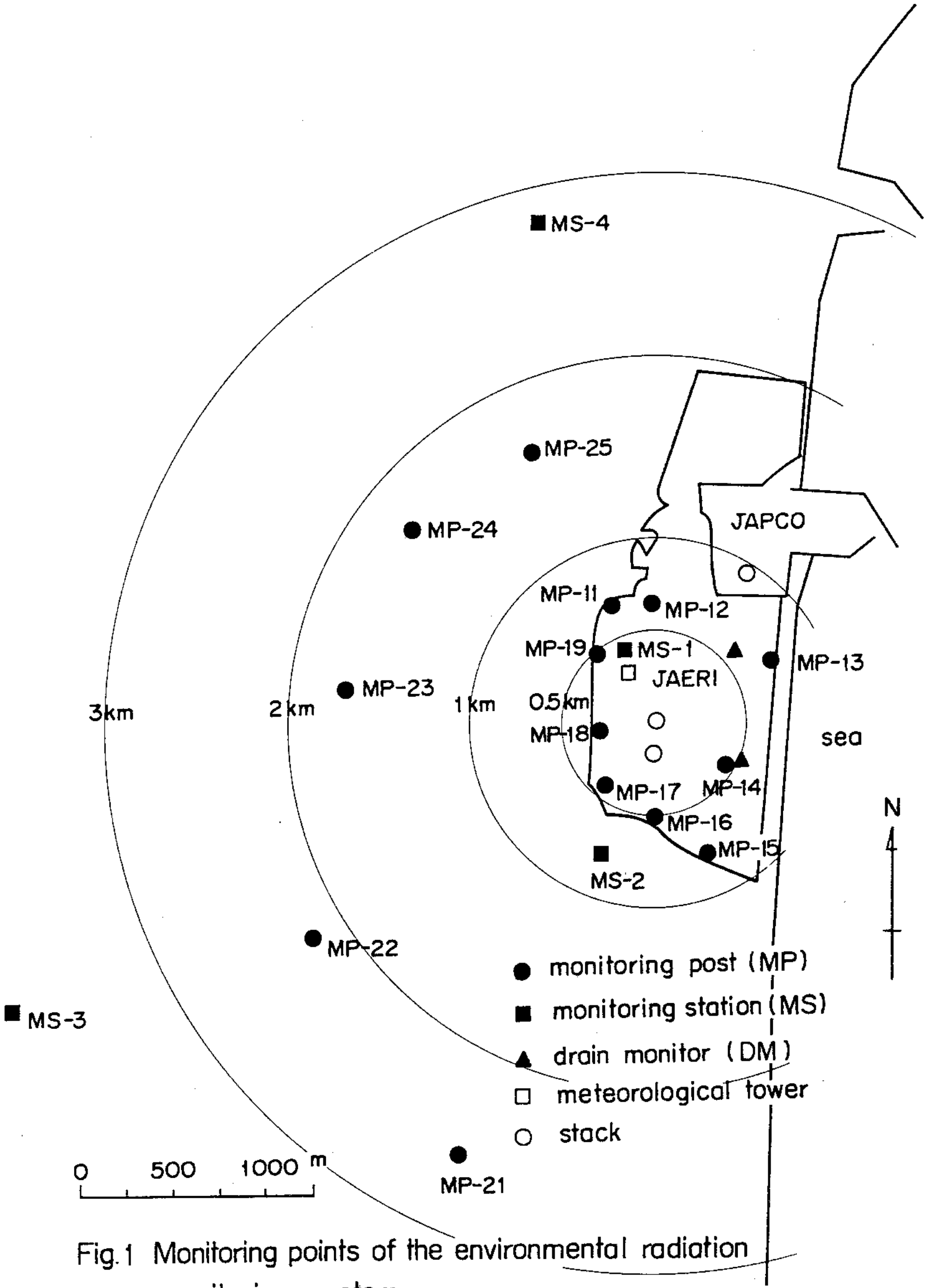


Fig. 1 Monitoring points of the environmental radiation monitoring system

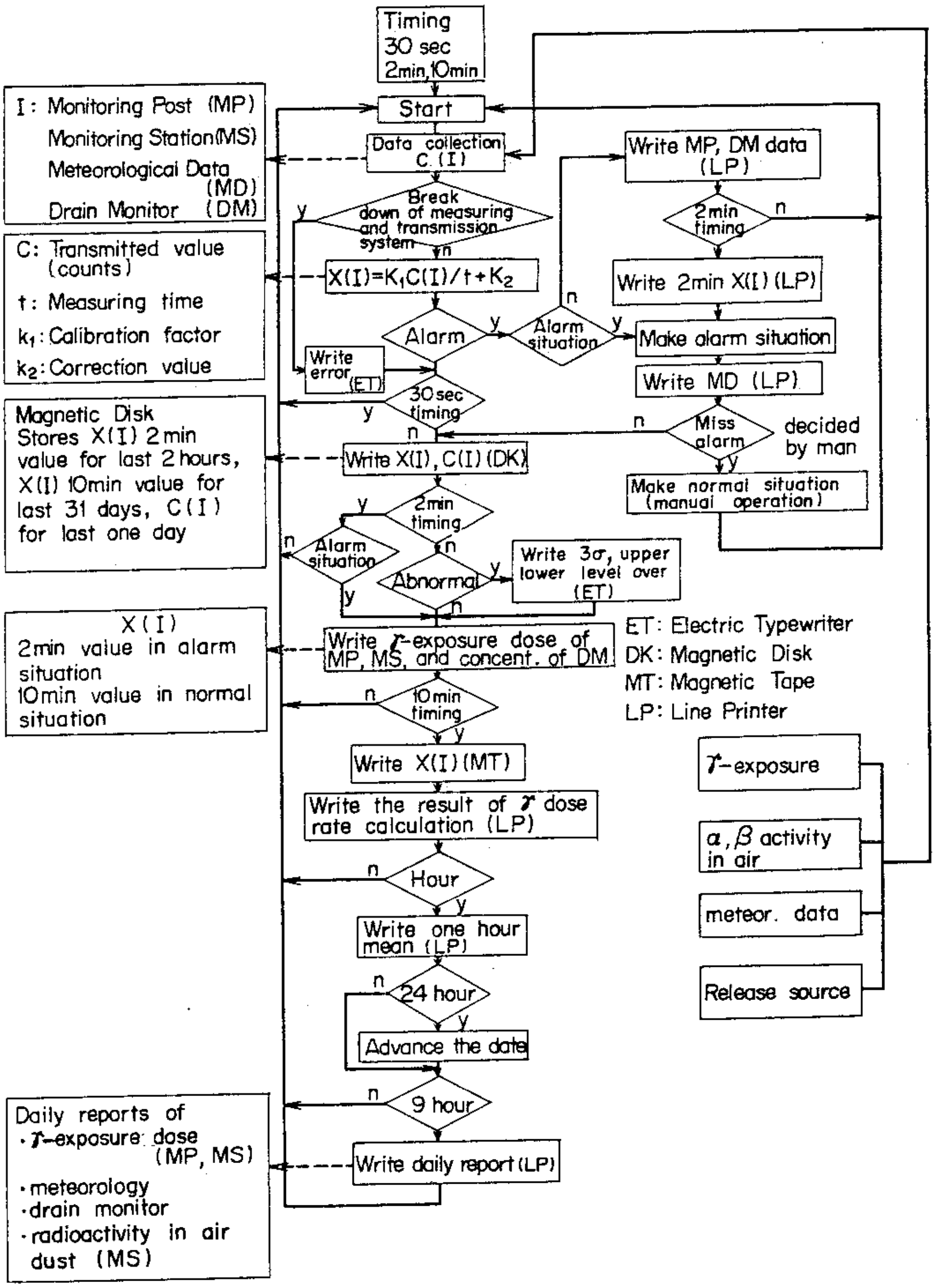


Fig. 2 Environmental radiation monitoring program (main)

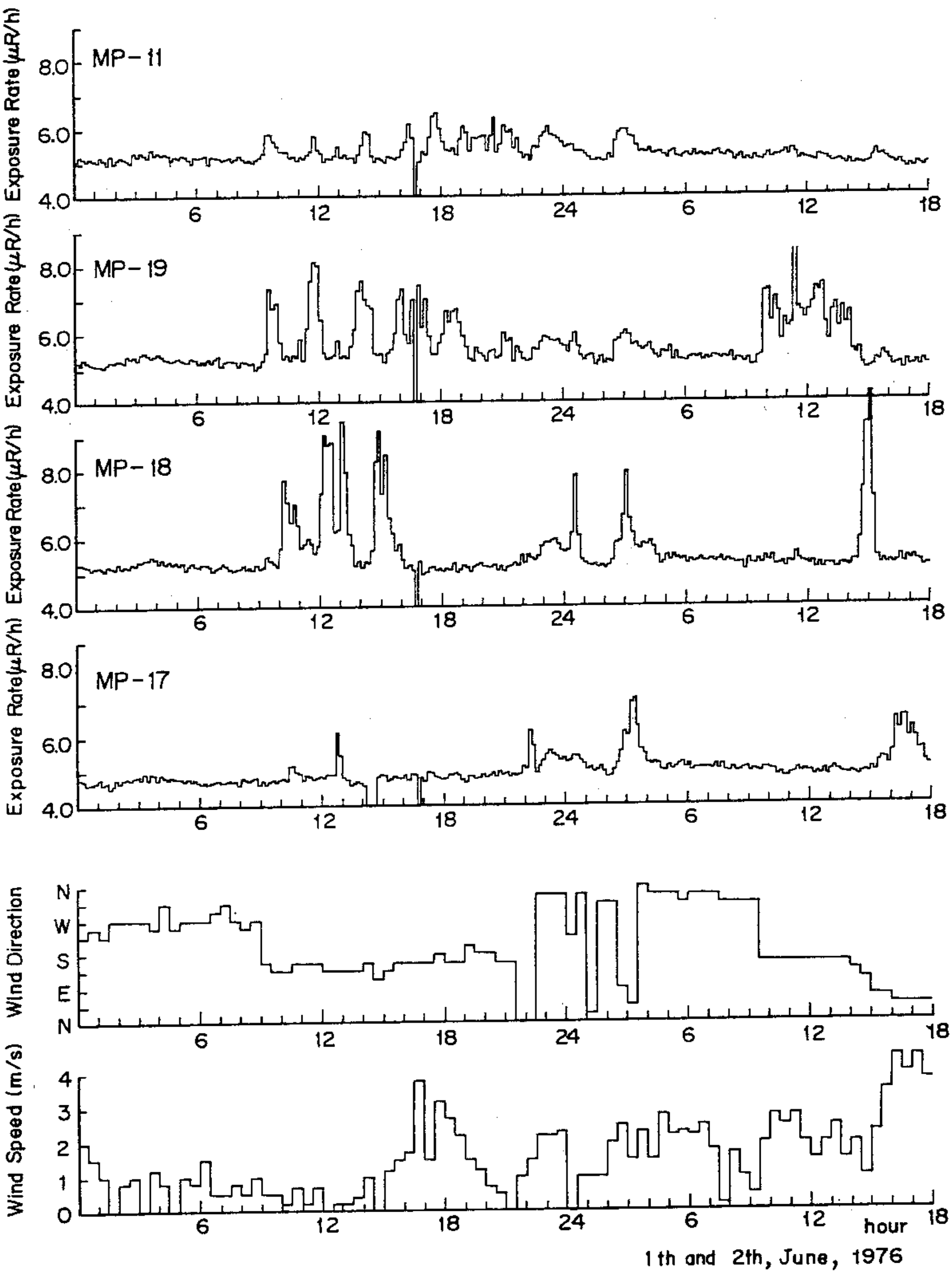


Fig. 3 Variation of γ-exposure rate caused by the ^{41}A from JRR-2 (release rate : 0.47 Ci/h)

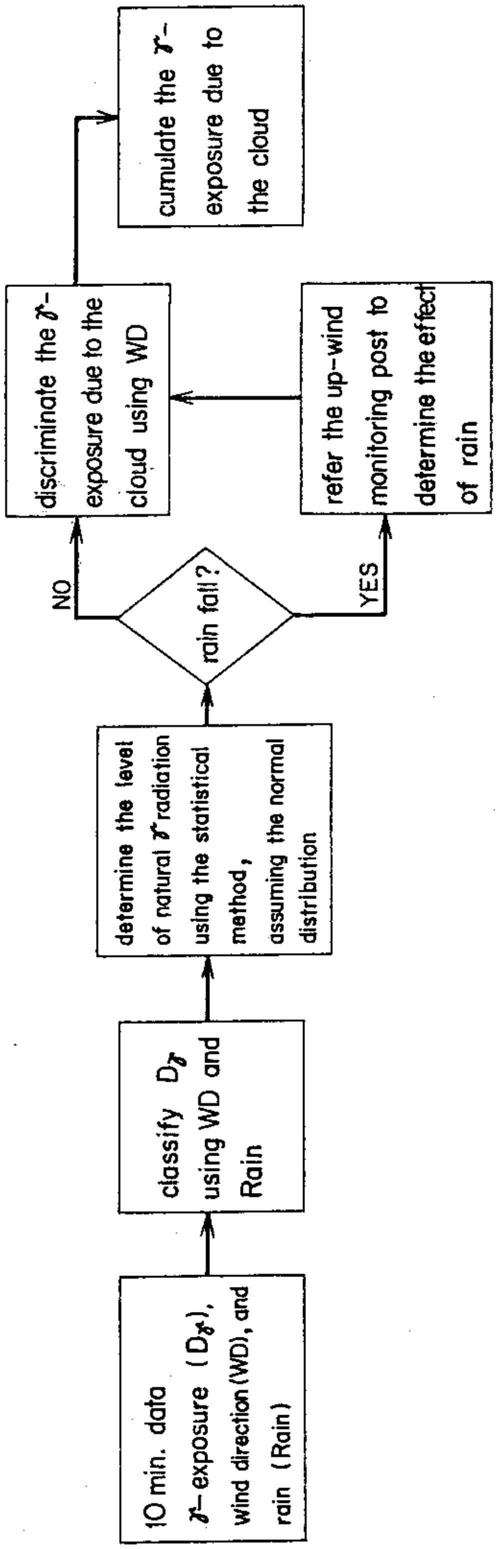


Fig. 4 Flow chart of data analysis

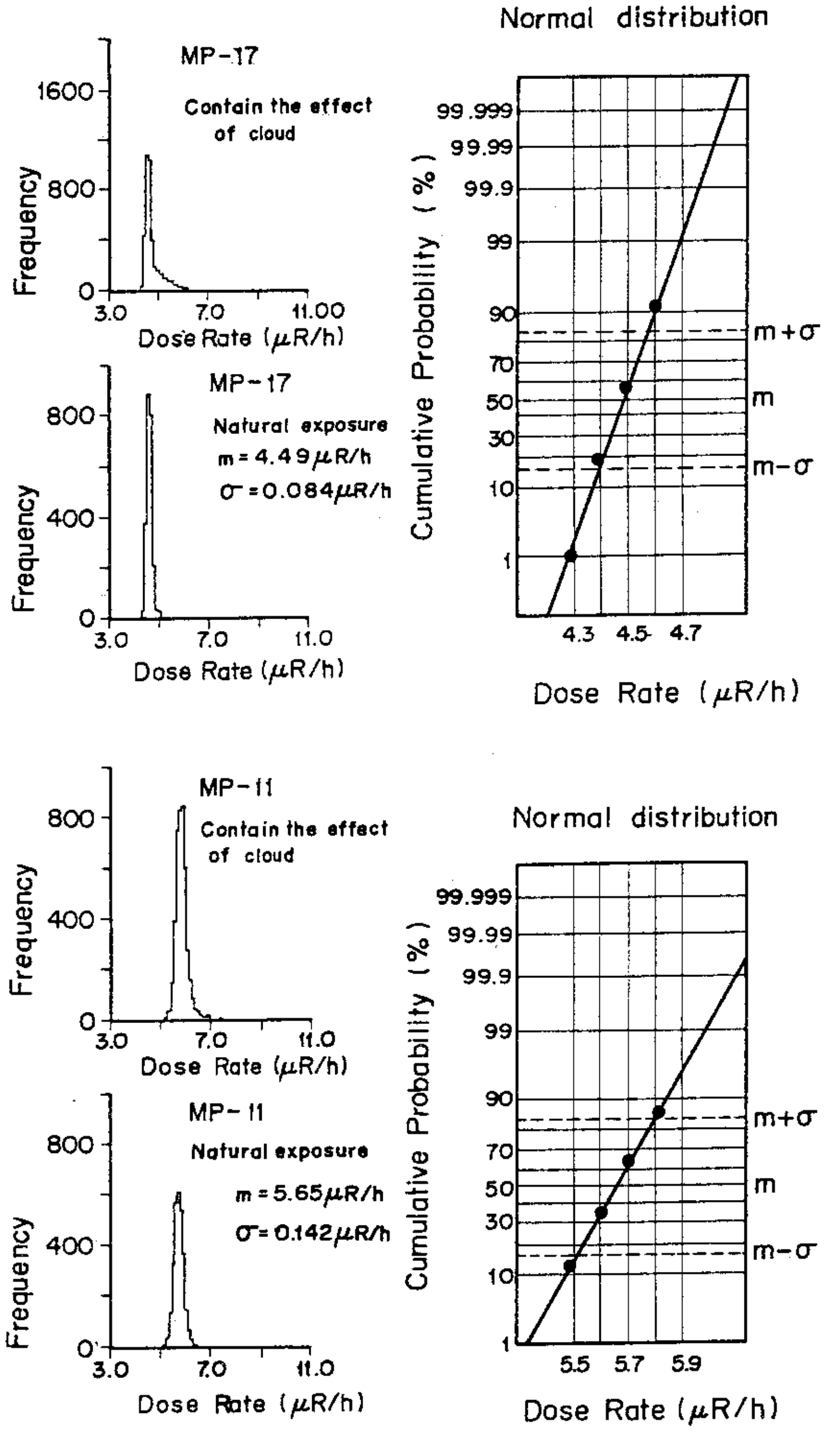


Fig. 5 Monthly mean and standard deviation of natural γ-exposure derived from the statistical method

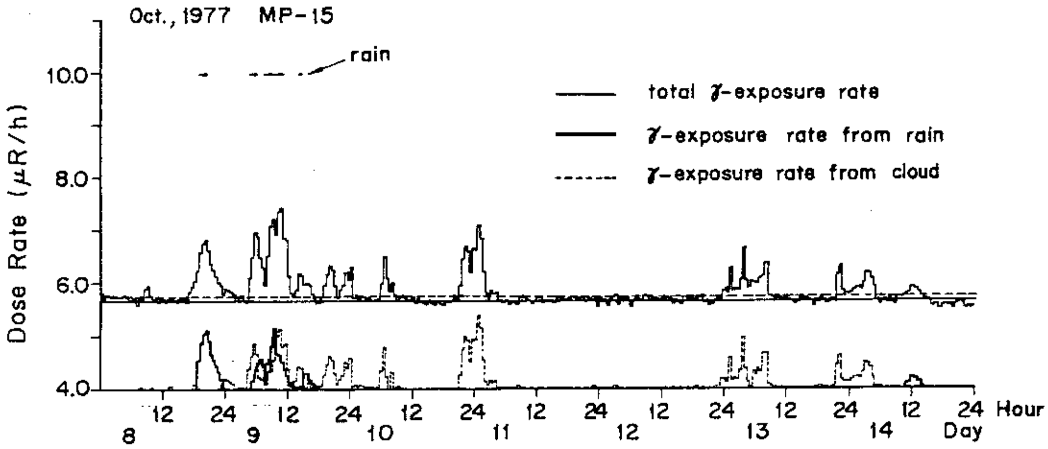
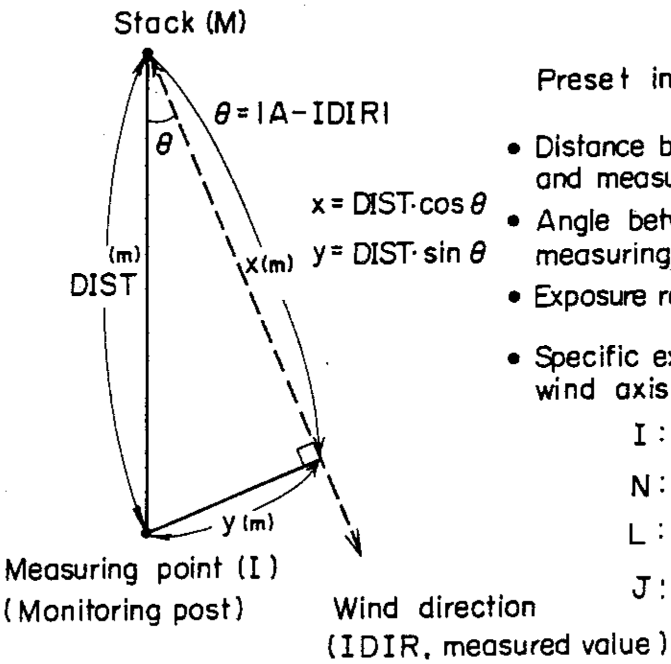


Fig. 6 Result of the separation



Preset input data

- Distance between stack and measuring points — DIST(I,M)
- Angle between stack and measuring points — A(I,M)
- Exposure rate on down wind axis(x) — DO (I,M,N,L)
- Specific exposure rate on cross wind axis (y) — CON (I,M,N,J)

I : measuring point M : stack

N : atmospheric stability

L : DIST and (DIST−200) m

J : 200, 400, 600, 900, 1200, 1500m

Fig. 7 Method of exposure dose calculation (EMS method)

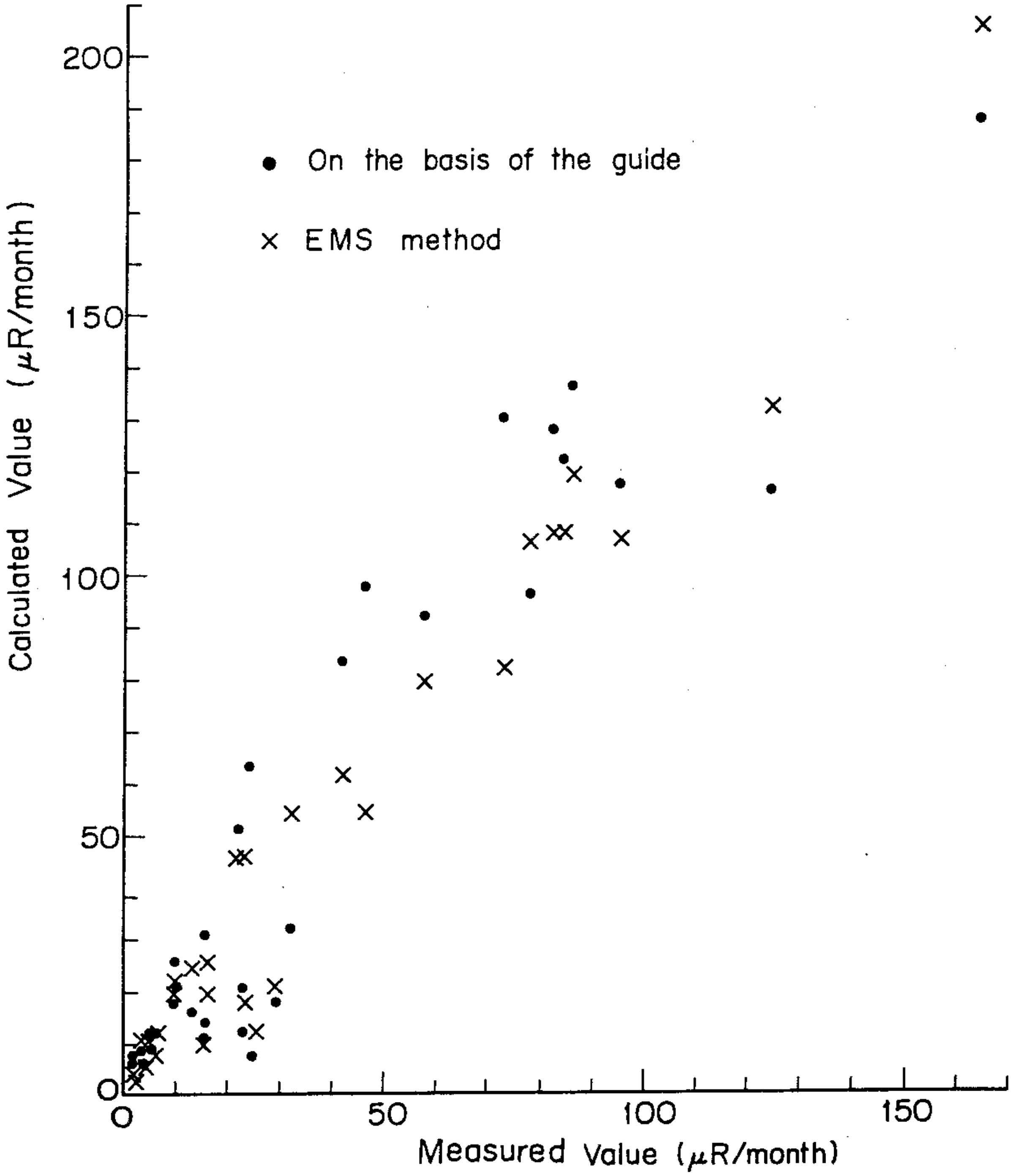


Fig.8 Correlation between calculated and measured value