

# Environmental Dose Analysis From Background Radiation in the Environmental Gamma Monitoring Stations at Kalpakkam

G.Surya Prakash, R.Venkatesan, K.M.Somayaji and B.Venkatraman

*Indira Gandhi Centre for Atomic Research, Radiological Impact Assessment Section, Radiological Safety Division, Radiological Safety and Environmental Group, Kalpakkam-603 102*

Continuous dose rate recorded by the network of environmental monitoring stations at Kalpakkam is analysed for estimating the site dose profile with respect to the local climatology. The gamma dose rate recorded comprises of the natural background as well as the dose due to the designed release of Ar-41 gaseous activity from Madras Atomic Power Station. The annual dose rate data at various stations, its seasonal and daily variation, the wind sectorwise distribution and the summary of the measured data are described in this paper. Contributions from  $^{41}\text{Ar}$  is differentiated from the dose record and annual dose due to the plume is tabulated for each station. Correlation with the wind direction is presented so that the data set can serve as a bench mark for plume dispersion model validation.

## INTRODUCTION

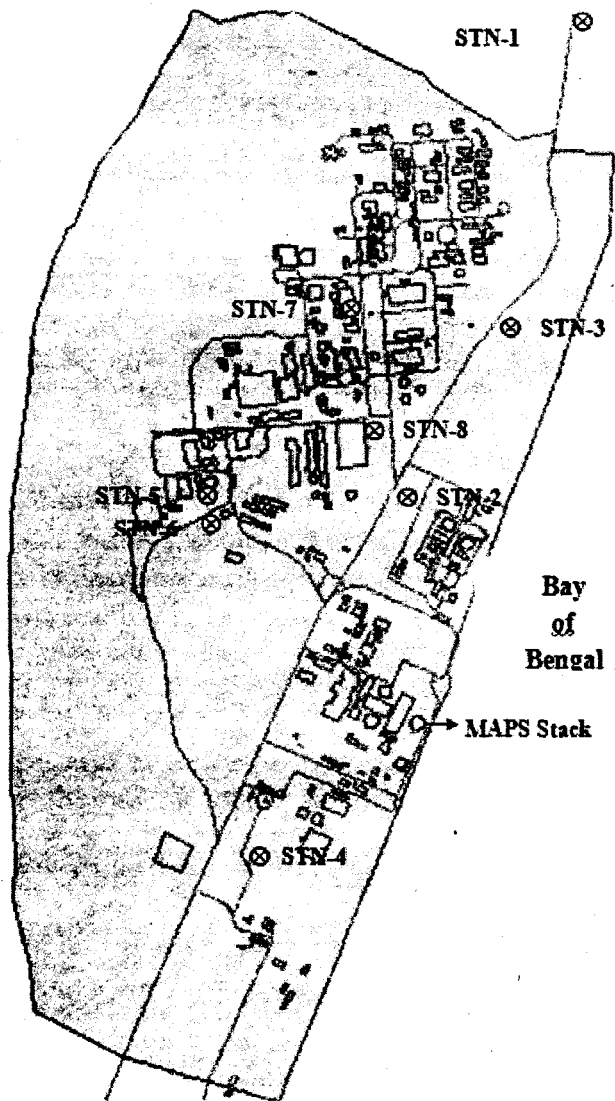
Kalpakkam site is becoming a multi nuclear facility complex and Madras Atomic Power Station (MAPS) is the main operating reactor presently. During the operation of MAPS, controlled quantity of  $^{41}\text{Ar}$  is released to the environment from a 100 m stack. Environmental monitoring of the nuclear facilities (Beck *et al.*, 1972; LLNL, 1994-1998) for nuclear radiation is mandatory and the data is used to assess the radiological consequences to the public due to routine releases, as well as if any under accidental conditions. Early detection of excess release in case of an untoward incident can also be done from these monitoring stations. When correlated with site meteorological data this measurement can provide very useful input for a reliable estimate of the source term, obviously vital information for the emergency response. Incidentally, the data also provides a measure of validation for the computer codes used for atmospheric dispersion modeling.

To meet these objectives in view, a network

of environment radiation monitors (IGC-197, 1993) is setup at selected locations in and around Kalpakkam to look for any abnormal increase in the background radiation levels, etc., and it has been operational continuously for a decade. The objective of the present work is to determine the  $^{41}\text{Ar}$  dose from the continuous measurements and correlate it with met data. The detector system, data archival technique and analysis of one year typical data is presented.

## SITE DESCRIPTION

Kalpakkam is situated near coastal area; the atmospheric characteristic of the near coastal area is distinctly different from an inland homogenous terrain. The paper describes the site map, location of continuous environmental monitoring stations are shown in figure 1. The locations of monitoring stations were decided on the basis of average annual wind rose for the site. As per the wind rose (IGC-197, 1993) and till date there is no significant change in wind climatology data. Hence the monitoring stations were located by covering south



**Figure 1.** Location of continuous environmental gamma monitoring stations at Kalpakkam

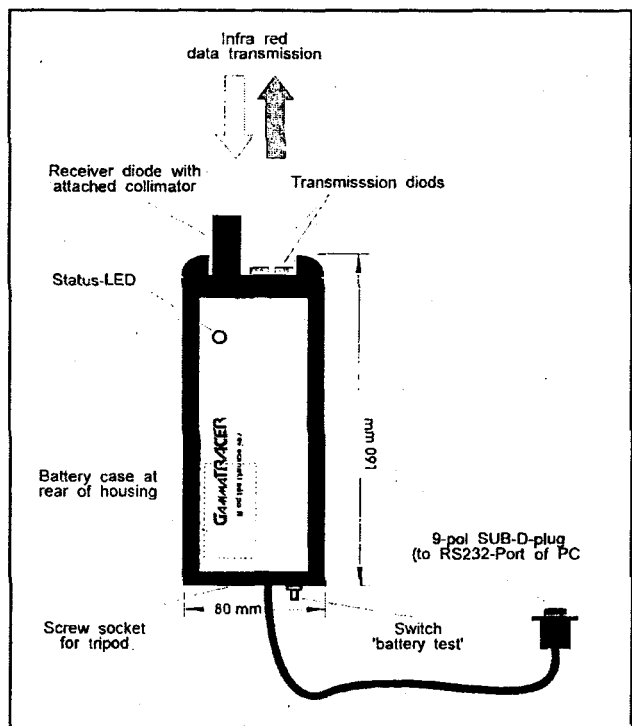
and north sectors. Some of the detectors are relocated in favourable wind conditions to cover the other sectors also.

**DESCRIPTION OF THE INSTRUMENT**

Environmental radiation monitoring network is set up with gamma tracers, a product of M/s Genitron. The instrument consists of an autonomous data logging (ADL) measuring probe for the continuous logging of the gamma dose rate. Each unit is equipped with two GM tubes, operating independent of each other. The result is normally given as a mean value of both detectors. The complete electronics including the power sup-



**Figure 2.** Typical photograph of the gamma tracer



**Figure 3.** Interactive RS 232 interface module

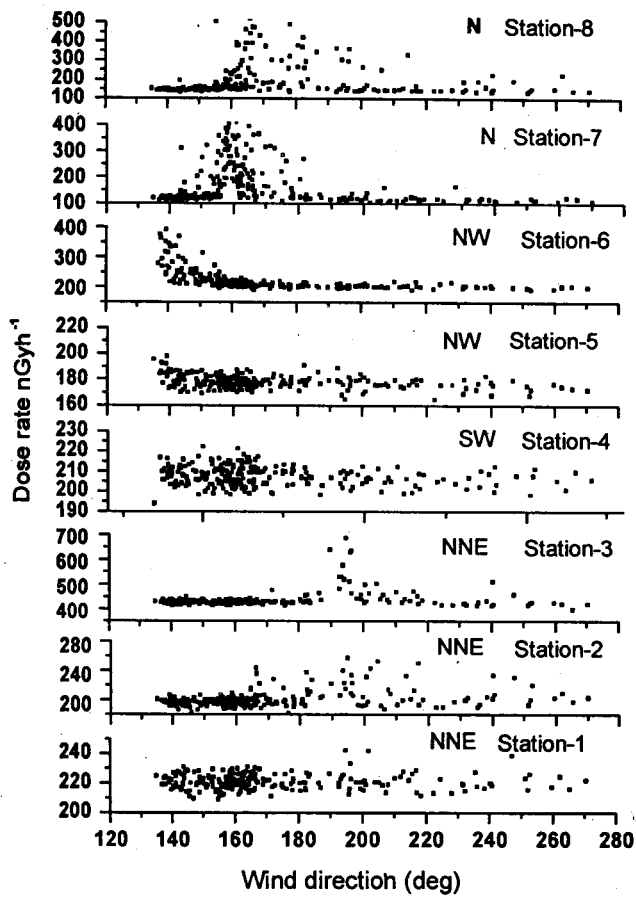


Figure 4. Variations in plume exposure dose rate due to change in wind speed and directions

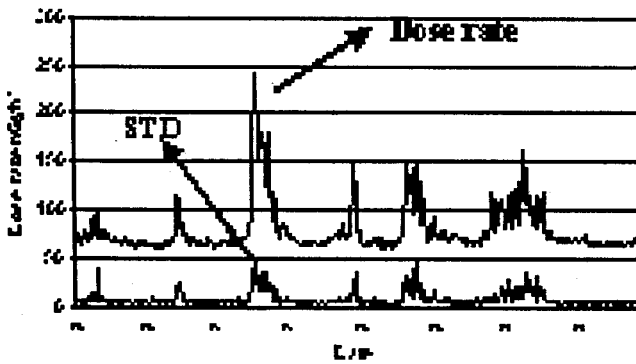


Figure 5. Typical environmental radiation data with standard deviation

ply drawn from lithium batteries is housed in a hermetically sealed casing. The energy-saving chip technology enables maintenance-free and permanent use of the gamma tracer for at least 5 year at a nominal dose rate. The typical photograph of the instrument and the interactive infrared interface

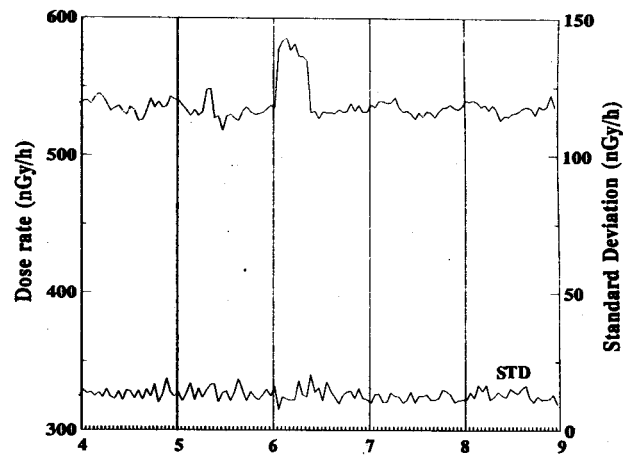


Figure 6. Correlation with source movement

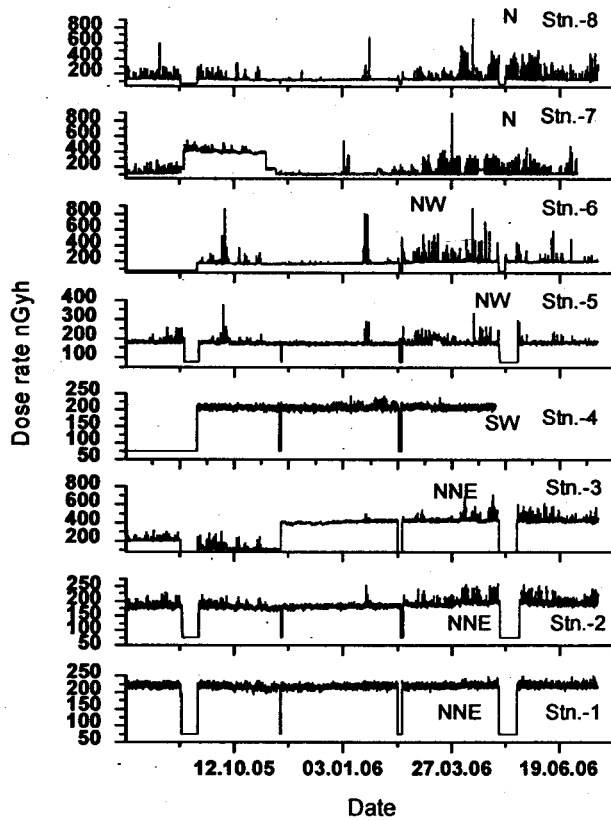


Figure 7. Annual data of all the environmental monitoring stations

RS 232 module for down loading the data from gamma tracer are shown in figures 2 and 3.

The user-friendly data analysis software gamma view enables a simple, safe access to stored data via an interactive infrared interface RS 232C. The software gives the

**Table 1.** Station of the wind sector with the distance from MAPS stack

Station no.	Wind sector	Distance from MAPS stack, km
1	NNE	4.0
2	NNE	0.3
3	NNE	2.0
4	SW	0.5
5	NW	0.6
6	NW	1.5
7	N	1.5
8	N	1.5

**Table 2.** Integral dose data for the period of June 2005 to July 2006

Station no.	Total dose, mSv	Total background dose, mSv	<sup>41</sup> Ar dose, mSv
1	1.761	1.759	0.002
2	1.508	1.480	0.028
3	2.692	2.618	0.076
4	1.121	1.109	0.012
5	1.463	1.429	0.034
6	1.466	1.370	0.096
7	1.433	1.333	0.100
8	1.265	1.131	0.134

parameters of photon dose rate, photon dose rate 1, photon dose rate 2, temperature, SYSQGT (hardware level) and DATQGT (data quality) and gives printing routines and graphic documentation. The data files can be converted into a data base in tabular ASCII-format. The sensitivity of the gamma tracer is 2.6 cps/mGy/hr and the measuring range is 20 nGy/hr-10mGy/hr. The archived data can be transferred through IR-transceiver module, that is used alongwith gamma tracer probe and a PC. This module consists of transmission and receiver IR diodes with attached collimator and status LED, working on 9V battery. The measurement cycle can be programmed 1 min to 2 hr. The measuring time is set at 1hr. The memory capacity is 128 kB and the data can be stored for 6 to 8 month.

## CORRELATION OF DATA WITH WIND DIRECTION

The environmental radiation measured at a monitoring station at any location has two components, one from the natural background over which is superimposed a component due to routine Ar-41 release from the power reactors stack at MAPS, Kalpakkam (IGC-197, 1993).

The exposure data shows that small contribution from plume overlaps a larger but not necessarily constant background. The plume contributions is characterised by a few rapidly varying and easily identifiable perturbations above slowly varying component. These perturbations are caused primarily by fluctuations in wind speed and direction and they also depend upon the distance of the monitoring station from the stack. Verification that a particular perturbation is due to the plume from a particular release point can be obtained by correlating the data with wind direction and wind speed. The data gathered from 8 different stations for the period of 1-10 April 2006, have been analysed during sea breeze time and the typical plot of the same is shown in figure 4. The station number, wind sector data and distance from the MAPS stack are given in the table 1.

It can be seen that the detectors located in different sectors with respect to the MAPS stack, recorded dose only when the winds are towards the respective stations, whereas the stations at 3 and 5 detector has responded during land breeze time. It is observed that, even though the station 1 is in the same sector it has not responded during that time. This may be due to the release rate being too small to give rise to detectable concentration of Ar-41 at this distance.

## METHOD FOLLOWED TO DELINEATE OF <sup>41</sup>Ar CONTRIBUTION FROM THE DATA

The overall data for the period of one year (June 2005 to 2006) is taken for analysis. These raw data consist of integral dose rate

of natural background,  $^{41}\text{Ar}$  contribution from the permitted release from the Madras Atomic Power Station (MAPS) through 100 m stack and any constant radioactivity source movement near the station. One can easily identify by graphically looking at the raw data, the peaks are due to argon or constant source movement examples are given in the figures 5 and 6. A descriptive standard deviation method is adopted to extract the plume contribution (MAPS) and constant source movement.

The contribution due to  $^{41}\text{Ar}$  can be inferred after identifying the Ar peaks and subtracting the general background values. In each month, the average background dose was evaluated from raw data and the total background dose corresponding to the data recovery in the time series data hours was subtracted from the total dose shown for the month thus giving an estimate of the Ar dose. This methodology gave reliable results. And hence this method is now being followed for inferring Ar doses for all the stations. Employing this method helps us to look for any trend in the general background dose values at each of the stations. Another advantage of this post processing method is that it is no longer necessary to archive the standard deviation values in the field and the data file need contain the 15 min average value with real time stamp. In table 1 integral dose data from various stations are tabulated for the period of July 2005 to June 2006.

The annual environmental data with Argon dose obtained at 8 stations are shown in table 2. In 7 stations the values are between 1.2-1.7 mSv/y. The values are very less as compare to prescribed limits (ISRP) for the nuclear installation (20 mSv/y). At station-3 the annual dose is 2.7 mSv, the value is slightly higher as compare to other station the reason is being ascertained. These indicate there has been no abnormal situation.

#### **STANDARD DEVIATION METHOD (STD)**

An accurate estimation of the exposure rate due to Ar-41 contributions would call for

more refined techniques since the gross background signal would contain contributions from a number of environmental sources in addition to that due to stack effluents.

The detection of possible increases of a few tens of nGy/hr due to gaseous effluents from a nuclear reactor, superimposed on a background of the order of 400-1000 nGy/hr which is not necessarily constant calls highly reliable, sensitive and accurate methods capable of unambiguously discriminating between contributions due to the plume and other sources. Techniques for analysis are available whereby increase in exposure rate due to gaseous effluents can be uniquely distinguished from variations in ambient background. These methods are based on certain characteristics, like different time variations of the signal which itself provides the necessary selectivity. It is one of the well known technique, such as standard deviation method can be followed to infer  $^{41}\text{Ar}$  it is known to be very appropriate and accurate analysis of such data with different time response components (Thie, 1973).

The standard deviation method is the most common measure of statistical dispersion, measuring how widely spread are the values in a data set. If the data points are close to the mean than the standard deviation is small. If many data points are far from the mean, then the standard deviation is large. If all the data values are equal then the standard deviation is zero. A small variation in natural background due to stack effluents ( $^{41}\text{Ar}$ ) can easily be detected in this method. It is also well known that the background environmental radiation includes components with characteristic time scale of fluctuations ranging from less than an hour to as high as days, months and even seasons (HASL 290).

A typical example of STD technique is incorporated and the result is shown in the figure 5. In figure 5 the 10 min data gathered and it is processed to obtain the standard deviation. The standard deviation val-

ues are checked and it is sufficiently high compared to the value for the normal background, that minute is labelled as one with a plume contribution. If the standard deviations are low enough to assume that they represent background only. Significant standard deviation peaks during 26th to 29th is observed. These peaks correspond to large signal excursion during the corresponding period. The absence of signal and standard deviation peaks during 26th-29th also is to be noted. Thus  $^{41}\text{Ar}$  peaks can be unambiguously identified and the excess dose data is estimated. With the standard deviation method one can easily identify the higher dose rates are due to plume contribution or source movement near the monitoring station.

In one of the station we observed peaks in the dose rate could not be explained on the basis of wind direction correlation. Figure shows a marginal increase of 50 nGy over the background during the period of 8 hr. The wind was not towards that sector during that period and there was no corresponding increase in standard deviation. Hence, the peak was not due to  $^{41}\text{Ar}$ . This peak was attributed to some source movement near the station. Later it was confirmed that a radioactive laden lorry was parked near the monitoring station. One can easily identify the increase of dose rate due to Argon-41 or source movement by adopting the standard deviation method. Thus, in addition to showing the large trends accurately and consistently, it can be used for accurate evaluation of the excess contribution due to  $^{41}\text{Ar}$ . The overall one year typical data of all environmental monitoring stations are shown in figure 7. During transferring and installing period the data is shown as 75 nGy/hr. The period from 4.9.05 to 24.11.05 the station 7 data was not considered due to detector failure. Due to withdrawn of the station-4 the data was not shown fully. The overall trend shows in figure 7 variations in plume exposure rate due to change in wind speed, direction and atmospheric turbulence occurs over time scales.

## CONCLUSION

The continuous environmental radiation monitoring network comprises of 8 stations and it is planned to augment/expand the network by adding more number of stations. With the implemented network all the stations data will be accessed and stored at a central data centre. Substantial variations in the plume contributions occur due to the changes in wind speed, wind direction and atmospheric turbulence. The data analysis technique based on the average background dose was evaluated and the total dose corresponding to the data recovery hours was subtracted from the total dose of the inferred  $^{41}\text{Ar}$  was successfully adopted for accurate inference of the excess dose due to  $^{41}\text{Ar}$  was evolved.

Gamma tracer system was successfully integrated into the system and the data recovery was 100 %. The life of the battery of the system is limited to 4-5 year, for replacement of the battery these units are to be sent to the manufacturer as the units are hermetically sealed. To overcome this problem, radiological surveillance instrument based on microcontroller with LAN connectivity is being designed to work on battery with solar power charges the battery. Thus, the development of such system, the environmental radiation monitoring network would fulfil significantly the radiological part of the requirement of the vision of developing a centralised real time monitoring and dispersion forecast system at Kalpakkam. To authenticate these radiation data we are planning to do dispersion experiments.

## ACKNOWLEDGEMENT

The authors are indeed thankful to Dr. Baldevraj, Director, IGCAR, who has inspired us to have a new vision and has given a new direction to the project. We thank Shri S.C.Chetal, Director, Reactor Engineering Group and Dr.B.Venkatraman Associate Director, Radiological Safety and Environmental Group who has encouraged us to expedite the implementation of the expansion of the network of environmental radiation

monitoring.

## REFERENCE

- Beck, H.L., *et al.* 1972. New perspective on low level environmental radiation monitoring around nuclear facilities. *Nuclear Tech.*, 14.
- Fukui, M. 2004. Twenty years of experience in monitoring argon-41 in a research reactor and decrease of its discharge into the environment. *Health Physics*. 86(4) : 384-396.
- Lauritzen, Bent, *et al.* 2003. Atmospheric dispersion of argon-41 from a nuclear research reactor : Measurement and modeling of plume geometry and gamma radiation field. *Int. J. Env. Poll.*, 20(1-6).
- LLNL. 1994-1998. Environmental report.
- Moller, Dade W. 2005. Review article on environmental health physics : 50 years of progress. *J. Health Physics*.
- Saindane, S., *et al.* 2003. On-line environmental radiological data acquisition system for nuclear facilities and sites. *Radiation Prot. Env.*, 26 (1-2).
- Shebell and Kevin M. Miller. 1996. Analysis of 18 years of environmental radiation monitoring data. *Env. Int.*, 22(Suppl. 1) : S75-S83.
- Song, M.K. and K.C. Tsui. 1991. Analysis of environmental gamma dose rate data obtained in Hong Kong 1987-1991. Royal Observatory, Hong Kong.
- Thie, J.A. Low-level environmental monitoring by fluctuations analysis.