*Atmósfera (1993)*, **6**, *pp. 145-153*

# $^7$Be on surface air, Laguna Verde area, Veracruz, Mexico

S. SALAZAR[1, 2] and T. G. JIMENEZ LIMA[1]

[1] *Planta Nucleoeléctrica Laguna Verde, Comisión Federal de Electricidad, Departamento de Ingeniería Ambiental Apartado Postal 53, Cd. Cardel, Veracruz, México*

[2] *Instituto de Geofísica, Observatorio de Radiación Solar, Universidad Nacional Autónoma de México, 04510 D. F., México*

(Manuscript received Feb. 18, 1992; accepted in final form Oct. 19, 1992)

RESUMEN

El aerosol atmosférico natural y antropogénico además de su importancia en los procesos meteorológicos y climatológicos, sirve como superficie de adhesión de ciertos isótopos. Uno de estos casos es el del radionúclido cosmogénico $^7$Be. En el presente estudio se muestran los niveles de la concentración del $^7$Be determinados en aire en superficie, en 9 estaciones de muestreo localizadas cerca de la costa del Golfo de México, en latitudes tropicales. Se encontró una relación entre las concentraciones máximas detectadas de $^7$Be y la presencia de masas de aire polar (época de secas), y entre la concentración mínima del $^7$Be con la época de lluvias, coincidente con la presencia de sistemas de perturbaciones tropicales.

ABSTRACT

Besides their importance in meteorological and climatological processes natural and anthropogenic atmospheric aerosols, serve as adhesive surfaces on radioactive isotopes. One of these cases is the cosmogenic radionuclide $^7$Be. In this paper, the concentration of $^7$Be in surface air is presented, as it is detected at nine stations located in a tropical latitude in a coastal location on the Gulf of Mexico. $^7$Be concentrations and regional scale systems are found related, between the maxima and the fronts of polar air masses and between the minima with rainfall coincident with systems of tropical disturbances.

## Introduction

A number of radionuclides that exist on the surface of the Earth and in the atmosphere have been produced by the interaction of cosmic rays with atmospheric nuclei. The most important of these are tritium $^3$H, $^{14}$C, and $^7$Be (Junge, 1963; NCRP, 1975; Eisenbud, 1987).

The $^7$Be determination is used to know the mixture or movement of air masses from stratospheric to tropospheric layers (Lal and Peters, 1962; Parker, 1962; Bhandari *et al.*, 1966). From the concentration of $^7$Be and other radionuclides, whose presence can be quantified, other authors also have estimated the radiation doses on man due to cosmogenic radiation within the total of natural exposure (Brodzinski *et al.*, 1969; Liboff, 1975; Archundia *et al.*, 1992).

The set up of the Laguna Verde Nucleoelectric Facility (PNLV), in the State of Veracruz, Mexico, called to establish an Environmental Radiological Monitoring Program (PMRA) in the region. The studies were started in order to determine the background radiation of the area, and they have continued as a surveillance of the environmental radiation levels. This study has the following principal purposes: 1) provide experimental information of $^7$Be concentration in surface air, as detected at nine sampling stations belonging to PMRA, and 2) to show its patterns of behaviour and interpretation through meteorological parameters and synoptic phenomena of the region.

## Methodology

### *Site of the study*

The site of study is located at 19° 43'N and 96° 24'W, covering an area within a radius of 70 km around the PNLV on the northeastern coast of the State of Veracruz, Mexico.

The climate of the area is semitropical, the typical meteorological characteristics are represented by the presence of polar air masses occurring during the winter and the beginning of the spring; and by tropical disturbances during the rainy season occurring in summer. The annual precipitation in the region is over 1,000 mm with an annual mean temperature of approximately 25° C. The Sierra Madre Oriental to the west of the study area, modifies the flow pattern of local winds, sea and land breezes (Hill, 1969; Jáuregui, 1975; IAPNLV, 1984).

### *Sampling*

The $^7$Be concentration data were obtained from the Environmental Radiological Monitoring Program of the Laguna Verde Nucleoelectric Plant, carried out during 1987-1990 (PMRA, 1987; 1990). The nine sample collecting stations are located within a radius not greater than 70 km from the PNLV site, and their location is shown in Figure 1 and Table I.

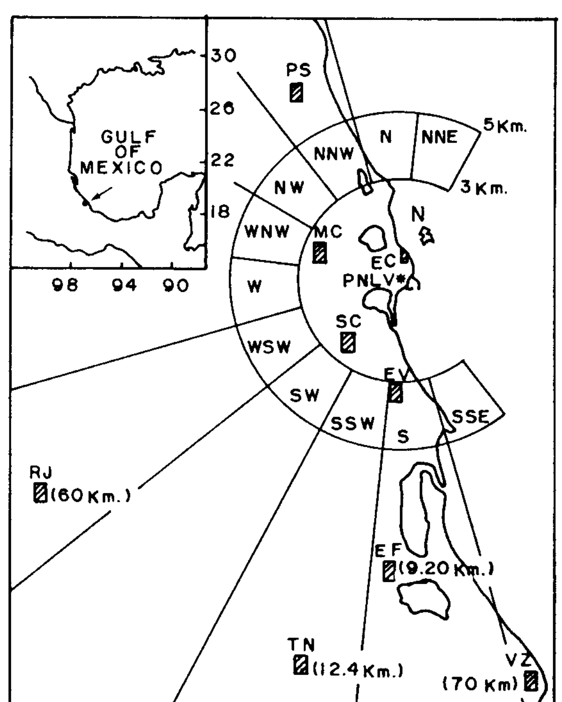


Fig. 1. Location of the Laguna Verde Nucleoelectric Plant and stations of sampling of particles.

Table I. Sampling stations, distance and position with respect to nuclear plant.

| Stations | Key | Distance (km) from nuclear plant | Position |
|---|---|---|---|
| Palma sola | PS | 6.00 | NNW |
| Monte Carmelo | MC | 2.00 | WNW |
| San Carlos | SC | 1.40 | SW |
| Tinajitas | TN | 12.45 | SSW |
| El Viejón | EV | 3.60 | S |
| El Farallón | EF | 9.20 | S |
| Estación climatológica | EC | 0.96 | NNE |
| Jalapa | RJ | 70.00 | WSW |
| Veracruz | VZ | 60.00 | SSE |

The sampling of the atmospheric particles was carried out using vacuum pumps of low volumes of air (Hi-Q Environmental Products Company, Scientific Co. Inc.), which were located 1.5 m above the ground. The air flow through the filter was 60 lpm., and as collecting medium Whatman EPM-2000 of 2" diameter and 0.3 $\mu$m pore size microfiber glass filters were used. The continuous sampling time for each samples was seven full days (168 hours). The samples analyzed for this study were 144.

The meteorological data were obtained from the PNLV climatological station (EC). For the measuring of precipitation, a Rossbach model R–10 rain gauge was used, recording daily precipitations. The stability categories, using the Pasquill–Gifford classification, were calculated with the temperature lapse rate method, which uses the bulk vertical temperature gradient between the levels from 10 to 60 meters (IAEA, 1980).

*Analysis*

Analyses were carried out with gamma spectrometry, using hyperpure Germanium detector, of 66 cc type Gem of 13% efficiency and with 2.2 KeV to 1.332 MeV resolution, with standard electronics and a G & E Ortec model 918 A multichannel analyzer. The system was calibrated with a mixed standard for the geometry of the Petri box. The acquisition time was from 7 to 14 hours for each sample and the lower limit of detection was 7.57 fCi/m$^3$.

## Results and discussion

The three–month concentrations of $^7$Be, at each of the nine stations and the annual averages are shown in Table II. The total annual average for the period of study 1987-1990 is 33.6 fCi/m$^3$, approximately, which is nearly the $^7$Be concentration reported for surface air by other authors (Feely *et al.*, 1989; Friend *et al.*, 1961; Feely *et al.*, 1971; Archundia *et al.*, 1992), both in tropical and in temperate latitudes (Rangarajan and Gopalakrishnan, 1970; Bhandari *et al.*, 1966; Reiter *et al.*, 1971; NCRP, 1975).

In observing the diagrams that show the three–month average $^7$Be concentrations, during 1987-1990 (Figure 2), we see, in general, that the maximum concentrations are detected during the first period of three months (January to March), corresponding to the end of winter and beginning of spring. The minimum concentrations are detected during the third period of three months (July to September), that corresponds to the summer.

TABLE II. Cocentration of Be-7 (fCi/$m^3$), stations of the PNLV, Veracruz, Mexico.

| YEAR | THREE MONTH PERIOD | STATION PS | MC | SC | TN | EV | EF | EC | RJ | VZ |
|---|---|---|---|---|---|---|---|---|---|---|
| 1987 | 1 | 74.2 | 91.6 | 75.2 | 64.9 | 56.0 | 92.6 | 68.1 | 53.3 | 80.1 |
| | 2 | 37.4 | 40.0 | 36.3 | 36.9 | 30.0 | 43.4 | 40.1 | 35.4 | 38.8 |
| | 3 | 28.4 | 12.6 | 21.3 | 18.4 | 15.8 | 82.0 | 21.2 | 12.7 | 20.9 |
| | 4 | 36 | 32.5 | 45.1 | 34.7 | 35.2 | 47.1 | 33.6 | 35.4 | 38.3 |
| | Average | 44.0 | 44.2 | 44.5 | 38.7 | 34.3 | 66.3 | 40.8 | 34.2 | 44.5 |
| | standard deviation | 17.8 | 29.2 | 19.7 | 16.7 | 14.4 | 21.4 | 17.2 | 14.4 | 21.8 |
| 1988 | 1 | 49.9 | 31.0 | 40.7 | 50.0 | 33.5 | 55.0 | 39.0 | 26.3 | 50.8 |
| | 2 | 55.1 | 40.0 | 39.3 | 34.2 | 24.8 | 42.4 | 32.4 | 32.6 | 34.3 |
| | 3 | 30.0 | 23.0 | 23.0 | 20.0 | 19.0 | 32.0 | 21.0 | 17.0 | 14.0 |
| | 4 | 27.0 | 23.0 | 35.0 | 21.0 | - | 34.0 | - | 28.0 | 15.0 |
| | Average | 40.5 | 29.3 | 34.5 | 31.3 | 25.8 | 40.9 | 30.8 | 26.0 | 28.5 |
| | standard deviation | 12.2 | 7.0 | 7.0 | 12.2 | 6.0 | 9.1 | 7.4 | 5.7 | 15.2 |
| 1989 | 1 | 31.0 | 47.0 | 33.0 | 30.0 | 28.0 | 41.0 | 35.0 | 26.0 | 36.0 |
| | 2 | 31.7 | 26.9 | 11.3 | 15.3 | 70.2 | 32.6 | 12.9 | 22.9 | 25.8 |
| | 3 | 25.0 | 22.4 | 20.8 | 12.5 | 22.6 | 24.3 | 20.5 | 23.1 | 39.4 |
| | 4 | 18.0 | 17.2 | 16.3 | 18.0 | 16.0 | 20.0 | 13.9 | 16.7 | 14.8 |
| | Average | 26.4 | 28.4 | 20.3 | 18.9 | 34.2 | 29.5 | 20.6 | 22.2 | 29.0 |
| | standard deviation | 5.5 | 11.3 | 8.1 | 6.7 | 21.2 | 8.1 | 8.8 | 3.4 | 9.6 |
| 1990 | 1 | 28.0 | 45.0 | 32.0 | 42.0 | 19.0 | 20.0 | 19.0 | 30.0 | 60.0 |
| | 2 | 48.0 | 19.0 | 37.0 | 25.0 | 24.0 | 29.0 | 32.0 | 52.0 | 46.0 |
| | 3 | 36.0 | 14.0 | 36.0 | 28.0 | 28.0 | 39.0 | 19.0 | 42.0 | 42.0 |
| | 4 | 52.0 | 22.0 | 43.0 | 28.0 | 21.0 | 41.0 | 37.0 | 22.0 | 40.0 |
| | Average | 41.0 | 25.0 | 37.0 | 30.8 | 23.0 | 32.3 | 26.8 | 36.5 | 47.0 |
| | standard deviation | 9.5 | 11.9 | 3.9 | 6.6 | 3.4 | 8.4 | 7.9 | 11.4 | 7.8 |

The seasonal pattern of behavior obtained for $^7$Be concentrations in surface air at Laguna Verde sites was similar to that of other places in temperate and tropical latitudes (Feely *et al.*, 1989). These authors mention that at least four factors are important in causing the seasonal variation in $^7$Be concentrations. These are:

- The increase in the rate of transport of stratospheric air, containing high concentrations of $^7$Be, into the troposphere during the late winter and early spring seasons.
- The decreased stability of the troposphere during the warmer months, with a resultant increased rate of vertical transport from the upper troposphere to the middle and lower troposphere and into the surface air.
- Specially for high latitude is the transport of tropospheric air masses from middle latitudes into the high latitudes.
- Variations of the rate of washout of the atmospheric aerosol that carries the $^7$Be as seasonal changes in precipitation rate occurs in the air masses reaching a sampling site.

To interpret this pattern of behaviour, the local meteorology of the study area and regional scale systems were examined.

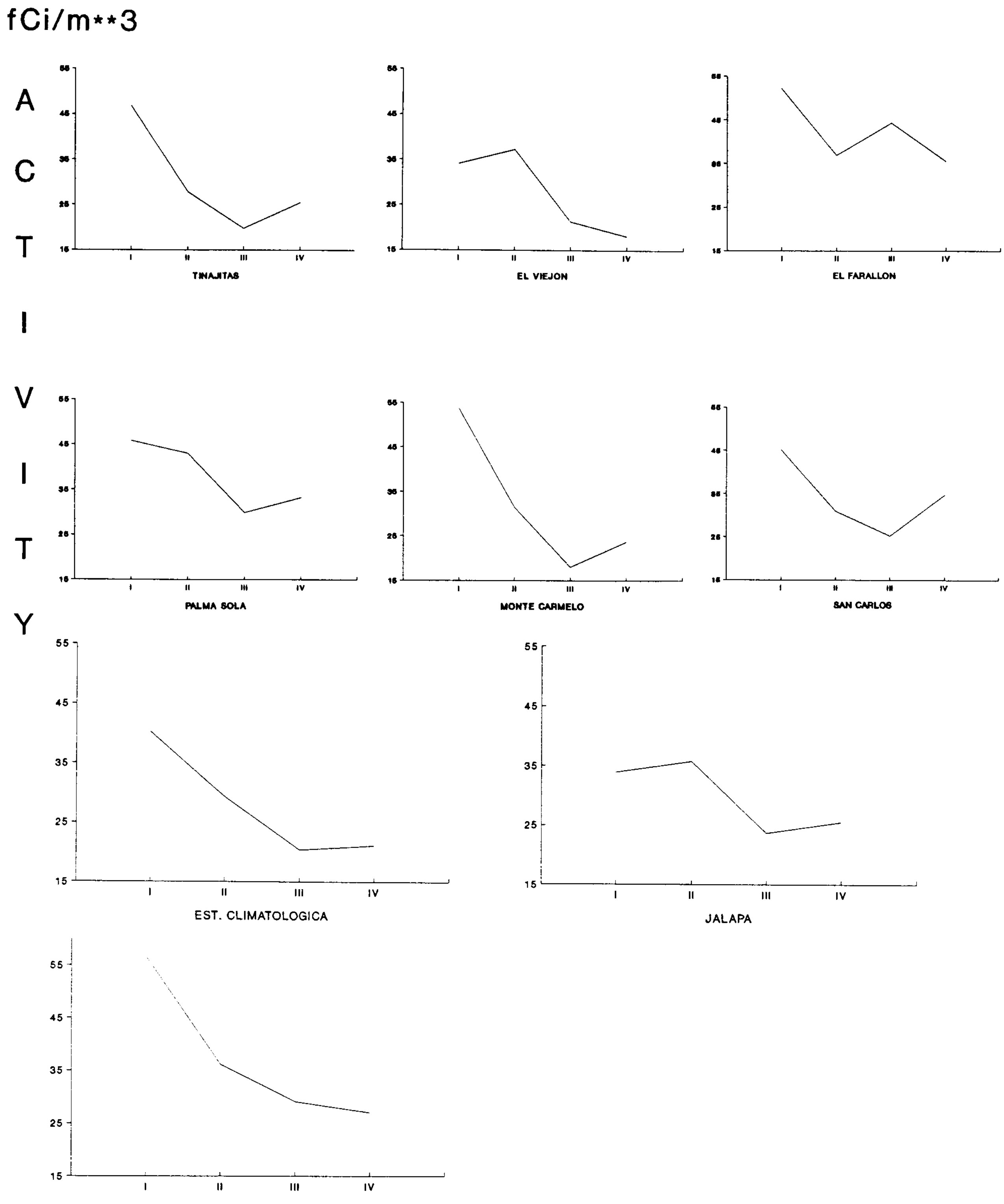


Fig. 2. Concentration of average Be–7 per three-month period (1987-1990). Stations of the PNLV, México.

*Precipitation*

The rainy season in the study area generally occurs from June to October, being primarily of the convective type associated with the disturbances produced by the humid trade winds. These reach the coast and develop more intensely because of the orographic effect of the mountains, which almost reach here the coast (to the W of PNLV). The average number of rainy days/year is 106, and the total annual average of rainfall is 1500 mm, approximately (IAPNLV, 1984).

In Figure 3 one can observe that during the study period of 1987-1990, the maximum precipitation occurred during the third trimester (July–September), coincident with the lowest $^{7}$Be concentration trimester recorded at almost all of the sampling stations (Figure 2). This low concentrations of summer is the effect of the precipitation rate (washout) on the atmospheric aerosol that carries the $^{7}$Be.

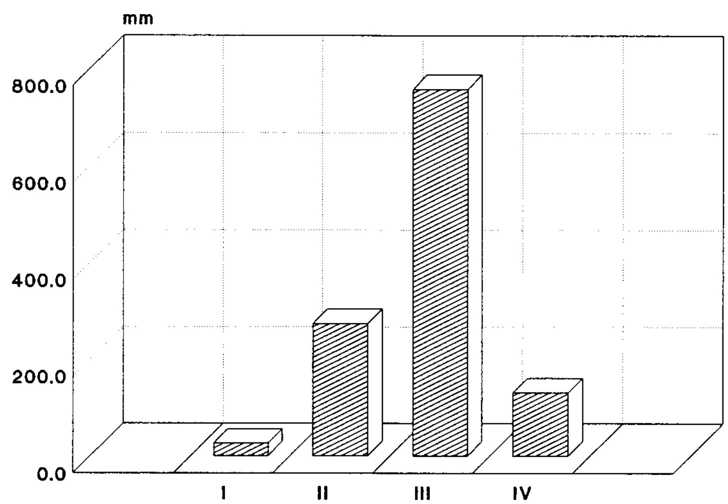


Figure 3.- Average rainfall per three-month period climatological station (1987-1990)

*Fronts of polar masses*

During the winter (dry season), the region is under the influence of circulation of westerly winds. However, at levels lower than 700 mb ( $\sim$ 3 km), an anticyclonic cell, located in the center and south of the Gulf of Mexico, produces a weak circulation of winds that have a component from the east. During the cold months, the surface barometric pressure increases toward the north of the PNLV, due to the average position of the anticyclon of the Gulf. In this epoch of the year, one can observe a marked northerly gradient of temperature, due to polar air (IAPNLV, 1984).

Analyzing the synoptic information from the Servicio Meteorológico Nacional during 1987-1990 period, was observed that the fourth and first three–month periods, were greater frequencies of polar air masses in the study area than the rest of trimesters.

Polar air fronts presence during the winter and beginning of the spring in the study area, which are coincident with the maximum $^{7}$Be concentrations, induces us to suppose that the maximum concentrations are produced by the presence of polar air masses coming from middle latitudes, or from near the poles, transporting stratospheric particles to the sampling sites (tropical latitude).

*Surface winds*

The regimes of surface winds are affected by the local topography. During the day, the breeze shows an easterly component; during the remainder of the day the land breeze has a component from W, NW, WNW and SW. During the dry season, the frequency of N and W components is increased (polar air mass), and during the rainy season, the winds are from the south and east.

*Atmospheric stability*

Considering the concentration of a pollutant at surface level is affected by the atmospheric stability, this parameter was also analyzed as a moderator of vertical transport. It is evident, from Figure 4, that the dominating categories are D and E, which correspond to a neutral and slightly stable atmosphere, respectively; therefore, a poor vertical mixing condition exists throughout the year. However, the presence of a land–sea interphase near the climatological station indicates that when the air–flow is toward land (sea breeze), a zone develops where the vertical mixing is limited by the internal boundary layer (Jones, 1985). Probably because of this, no direct relation was found between this parameter and the $^7$Be concentration. More detailed studies are needed to determine if any relation exists among these.

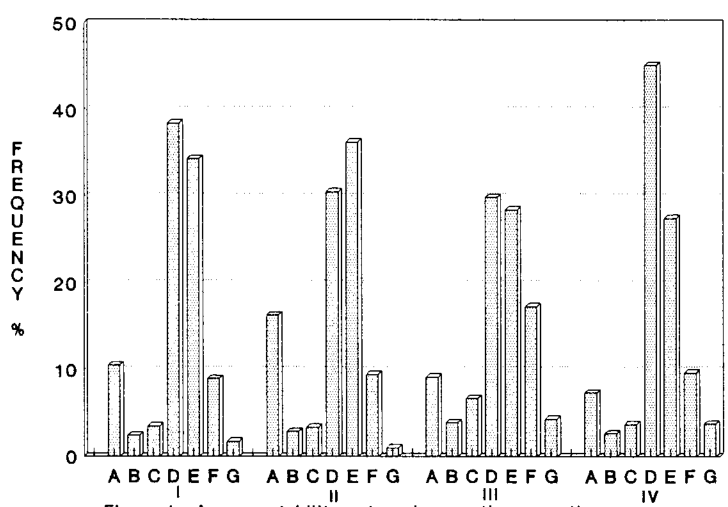


Figure 4.- Average stability categories per three-month period, climatological station (1987-1990)

## Conclusions

The typical synoptic phenomena of the study area shows a high frequency of polar air masses during the winter and beginning of the spring, coincident with the dry season and with the maxima of $^7$Be; and tropical disturbances coincident with the rainy season and minimum concentrations.

The slight increase that is observed during the first period of three months of the year could be ascribed to the movement of polar air masses carrying particles of stratospheric origin from high or middle latitudes to low latitudes.

The low concentration of summer is the effect of the rate of precipitation (washout) on the atmospheric aerosol that carries the $^7$Be.

**Acknowledgements**

The authors are greateful to the Management of the Laguna Verde–CFE Nucleoelectric Plant, for the help provided in carrying out this study; to the sampling group of the Dosimetry and Environmental Monitoring Laboratory of PNLV, CFE, for the preparation of filters and taking of samples; to R. Velázquez for his collaboration in the analyses of the samples and to R. Cruz for the preparation of figures. Very special thanks to M. Alcayde–Orraca, for the preparation of the English version of the mansucript.

REFERENCES

Archundia, C., B. E. González, S. R. Gutiérrez, E. Araico, 1992. Low–level measurements of cosmogenic Beryllium–7 in environmental samples. IX simposio internacional sobre química nuclear, radioquímica y química de radiaciones. 16-21 de agosto, Cuernavaca, Mor. México.

Bhandari, N., D. Lal and Rama, 1966. Stratospheric circulation studies based on natural and artificial radioactive tracer elements. *Tellus*, **18**, pp 391-406.

Brodzinski, R. L., N. A. Wogman and R. W. Perkins, 1969. Cosmic ray induced radioactivity in astronauts as a measure of radiation dose. *Space Life Sciences*, **1**, pp. 545.

Eisenbud, M., 1987. Environmental Radioactivity. Third Edition, Academic Press, Inc. Harcourt Brace Javanovich, Publishers, pp. 155.

Feely, H. W., J. P. Friend, H. Seits, J. D. Martin and W. E. Erlebach, 1971. Final report on project Stardust, U. S. Department of Defense Nuclear Agency Rept DASA 2166-3, Vol. 3, Chap. 10.

Feely, H. W., R. J. Larsen, G. C. Sanderson, 1989. Factors that causes seasonal variations in Beryllium-7 concentrations in surface air. *Journal of Environmental Radioactivity*, pp. 223-249.

Friend, J. P., H. W. Feely, P. W. Krey, J. Spar and A. Walton, 1961. HASP: Final report on the high altitude sampling program. US Department of Defense, Atomic Support Agency Rept DASA- 1300.

Hill, H., 1969. Temperature variability and synoptic old fronts in the winter climate of Mexico. McGill University, Climatological Series 4, Montreal, Canada.

IAPNLV, 1984. Informe Ambiental del Proyecto Nucleoeléctrico Laguna Verde. Comisión Federal de Electricidad, Cap. I. Secc. 1.3. Meteorología. Vol. 9.

Jáuregui, E., 1975. Los sistemas de viento en el Golfo de México y su vecindad. Vol. 6. Instituto de Geografía, UNAM, México.

Jones, J. A., 1985. Atmospheric dispersion- modelling coastal effects and wet deposition in probabilistic accident consequence assessments. National Radiological Protection Board, Chilton, Didcot. Oxon, OXII ORQ, pp. 18.

Junge, C. E., 1963. Air Chemistry and Radioactivity. Academic Press, New York, pp. 230-238.

IAEA, 1980. International Atomic Energy. Atmospheric dispersion in nuclear power plant siting. A Safety Guide, No. 50-SG-53, Vienna, pp. 38.

Lal, D. and B. Peters, 1962. Cosmic ray produced isotopes and their applications to problems in geophysics. In Progress in Cosmic Ray and Elementary Particle Physics, Vol. 6. North Holland, pp 3-74.

Liboff, A. R., 1975. Cosmic ray ionization in the lower atmosphere, in the Natural Radiation Environment II, J. A. S., Lowdwe, W. M. and Gesell, T., Eds. U. S. Atomic Energy Commission, Oak Ridge, Tenn, pp. 55.

NCRP, 1975. National Council on Radiation Protection and Measurements. Natural background radiation in the United States. Report No. 45, pp 8-41.

Parker, R. P., 1962. Beryllium–7 and fission products in surface air. *Nature*, **193**, 967-968.

PMRA, 1987; 1990. Programa de monitoreo radiológico ambiental. Proyecto Nucleoeléctrico Laguna Verde, Comisión Federal de Electricidad, México.

Rangarajan, C. and Gopalakrishnan, S. Smt., 1970. Seasonal variation of beryllium–7 relative to caesium- 137 in surface air at tropical and subtropical latitudes. *Tellus*, **22**, 115-121.

Reiter, R., R. Sládkovic, K. Pötzl, W. Carnuth and H. J. Kanter, 1971. Studies on the influx of stratospheric air into the lower troposphere using cosmic–ray produced radionuclides and fallout. Arch. Met. Geoph. Biokl., Ser. A, 20. 211-246.