

Using Natural ^7Be to Evaluate Upper-Air Transport of Aerosols and Gases in the Troposphere

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INTRODUCTION

Natural radionuclides have been proposed for use in assessing the transport of ozone and aerosols in the troposphere (1-2). For example, ^7Be is known to be produced in the upper troposphere and lower stratosphere by interactions with cosmogenic particles.

Beryllium-7 has a 53.28-day half-life and is a gamma emitter that attaches itself to fine particles in the atmosphere once it is formed. Indeed, in tropospheric aerosol samples ^7Be is typically found in association with aerosol particles that are $0.3\ \mu\text{m}$ in diameter.

Some investigators have asserted that ozone from aloft can be transported into rural and urban regions during stratospheric/tropospheric folding events, leading to increased background levels of ozone. Reported here are measurements of ^7Be taken at two sites near Pittsburgh, PA in the summer of 2001.

EXPERIMENTAL – SAMPLING

Samples were collected at two sites to examine the apparent residence times by using Sierra impactors (see Photo) and the number 4 plate for a submicron cut-off (aim particle size cut-off, D_{50} between $0.95 \mu\text{m}$ at a flow rate of $40 \text{ ft}^3 \text{ min}^{-1}$ and $1.10 \mu\text{m}$ at a flow rate of $30 \text{ ft}^3 \text{ min}^{-1}$).

The first site was located approximately 5 km east of downtown Pittsburgh on a building rooftop adjacent to Schenley Park (40.4395° N latitude and 79.9405° W longitude, at an altitude of approximately 310 m). At this site the wind was predominantly from the south and the west. The second site was located at the U.S. Department of Energy National Energy Technology Laboratory (NETL) Ambient Air Monitoring Station. This site is approximately 15 km south of downtown Pittsburgh (40.30655° N latitude and 79.9794° W longitude, at an elevation of 325 m above sea level). The wind at this site is predominantly from the south and southwest. At the sites, 24 hour samples were collected from July 22 to July 30, 2001 on quartz and cellulose filters. Air

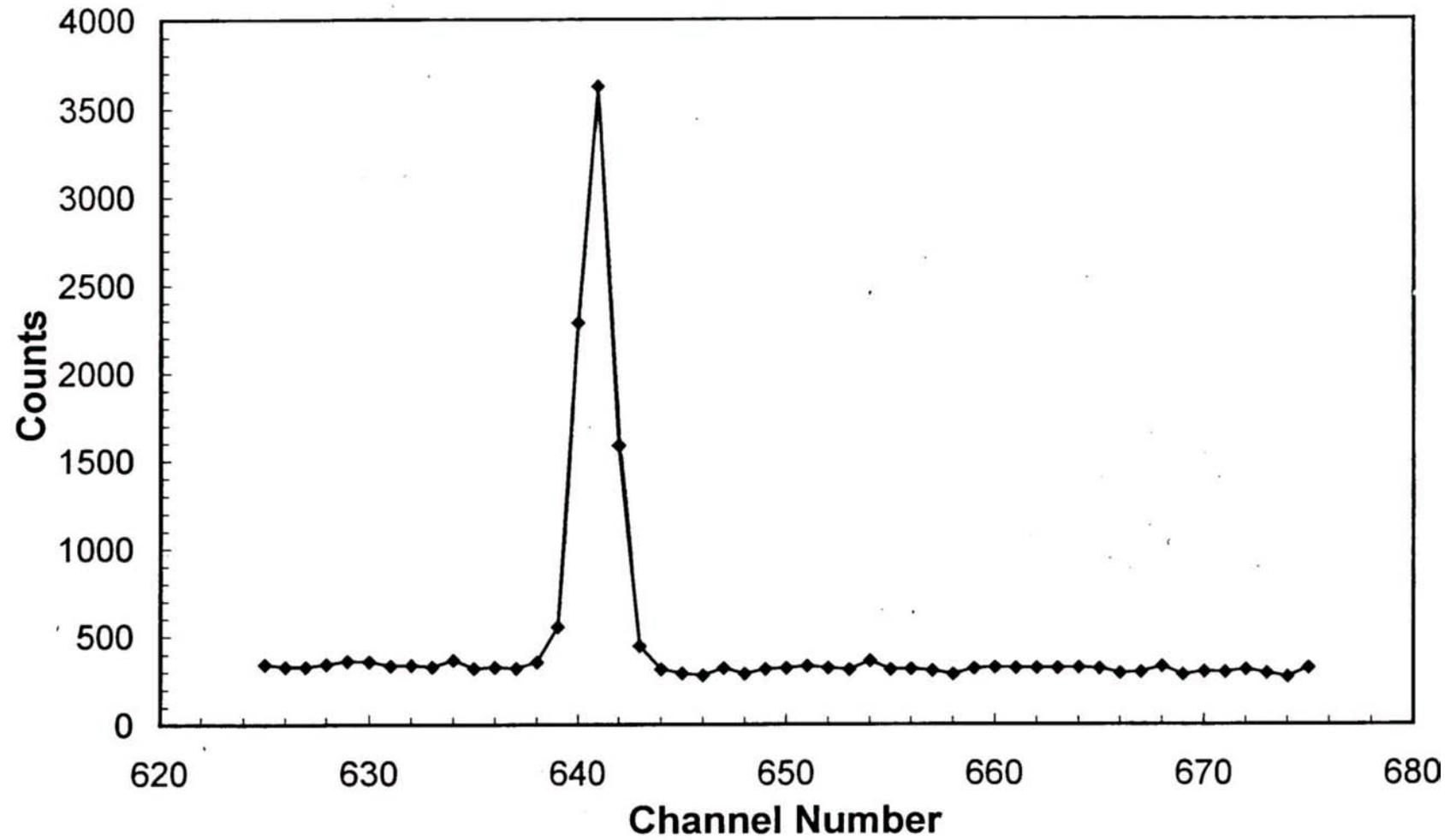
sample volumes ranged from 1320 to 1600 m³ of air. Nine samples were taken at the NETL (NT) site, and six were taken at the Schenley Park (SP) site.

Beryllium-7 Measurements

Beryllium-7 was determined by direct gamma counting of the filter membranes with a high purity germanium (HPGe) crystal detection analyzer (See Photo). This system allows for the direct measurement of ⁷Be attached to fine aerosol particles. Sample counting rates are corrected for geometry, detector response factors, and the relative decay rates of the gamma radiation versus total decay processes. The data are presented and compared to data obtained at Phoenix, AZ, in the summer of 2001 and in Houston, TX , in the summer of 2000.



^7Be Gamma Peak and Background on Multichannel Analyzer

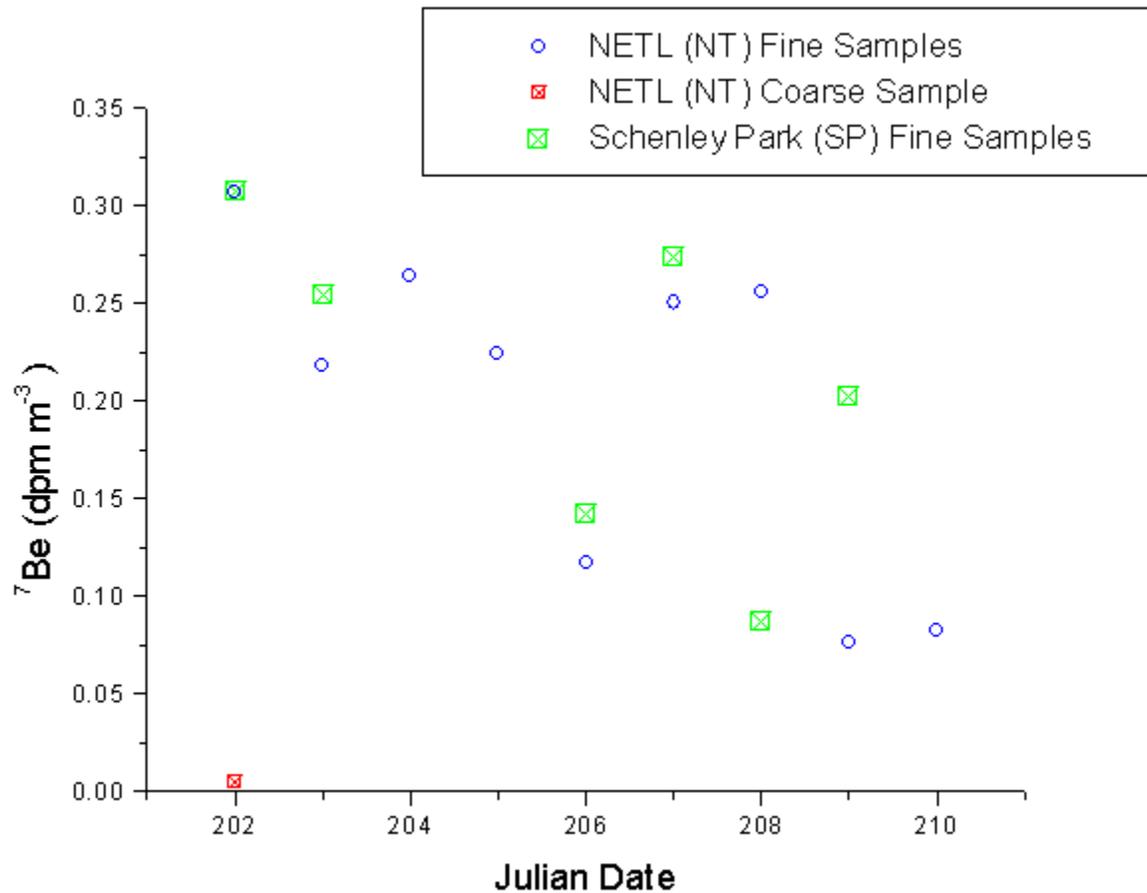


RESULTS

Observed ^7Be levels in disintegrations per cubic meter of air (dpm m^{-3}) for the Pittsburgh samples are given in Figure 1. NETL samples are labeled NT and the Schenley Park samples are labeled SP. All of the samples collected were fine aerosol fractions except for one coarse sample taken at the same time at the NETL site. This sample was examined and found to contain negligible amounts of ^7Be above our counting background blanks. This is consistent with the ^7Be being attached to 0.3-0.6 μm diameter aerosols that we and others have observed in past work on naturally occurring ^7Be in the troposphere (1,2). The actual values for the various samples are given in Table 1.

Table 1. NETL (NT) and Schenley Park (SP) field site ⁷Be Measurements. All samples were on the fine fractions with the exception of one coarse sample taken at NETL at the beginning of the sampling period. Corrected values are for the time delay in analysis and the radioactive decay of the ⁷Be.

Date and Sample No.	Sampling Site and Type	⁷ Be (dpm)	Volume (m ³)	dpm m ⁻³	Corrected dpm m ⁻³	Atoms ⁷ Be m ⁻³
7 22 01 1	NT-fine	440	1471	0.299	0.307	34016
7 22 01 2	NT-coarse	6.5	1471	0.0044	0.005	509
7 22 01 3	SP-fine	395	1353	0.291	0.307	34052
7 23 01 4	NT-fine	293	1432	0.204	0.218	24151
7 23 01 5	SP-fine	314	1355	0.231	0.254	28139
7 24 01 6	NT-fine	354	1462	0.241	0.264	29339
7 25 01 7	NT-fine	289	1410	0.205	0.224	24903
7 26 01 8	NT-fine	169	1572	0.107	0.117	13021
7 26 01 9	SP-fine	198	1545	0.127	0.142	15728
7 27 01 10	NT-fine	353	1605	0.220	0.250	27758
7 27 01 11	SP-fine	351	1472	0.238	0.274	30451
7 28 01 12	NT-fine	302	1358	0.222	0.256	28401
7 28 01 13	SP-fine	121	1385	0.087	0.100	11130
7 29 01 14	NT-fine	105	1589	0.066	0.076	8444
7 29 01 15	SP-fine	278	1609	0.172	0.202	22388
7 30 01 16	NT-fine	95	1329	0.0718	0.082	9114
Blank Filter		1.8				
Blank Filter		0.8				



Very good agreement for the samples taken on July 22, 23, 26, and 27 can be seen for the ^7Be data at the two sampling stations. On the 28th the NT site was about a factor of two higher than the SP site, albeit these are still fairly low levels of ^7Be in the air. The sample on the 29th was just the

opposite, with the SP site being higher than the NT site. Generally we have seen that sites that are within a twenty mile distance of each other track fairly well, indicating that ^7Be is a fairly good measure of regional air transport. For most of this period we observed this same type of phenomena. Other reasons for the differences between the two samples, also includes reduced air flow in the samplers, which can be caused by a number of situations including intermittent power outages or brown outs at the field sites.

^7Be temporal behavior for similar sampling at 12 hour and 6 hour sampling frequencies (see Photo) from recent data taken in Houston, Texas as part of the Texas 2000 Air Quality study, and the Phoenix 2001 field study, respectively, are shown in Figures 2 and 3.

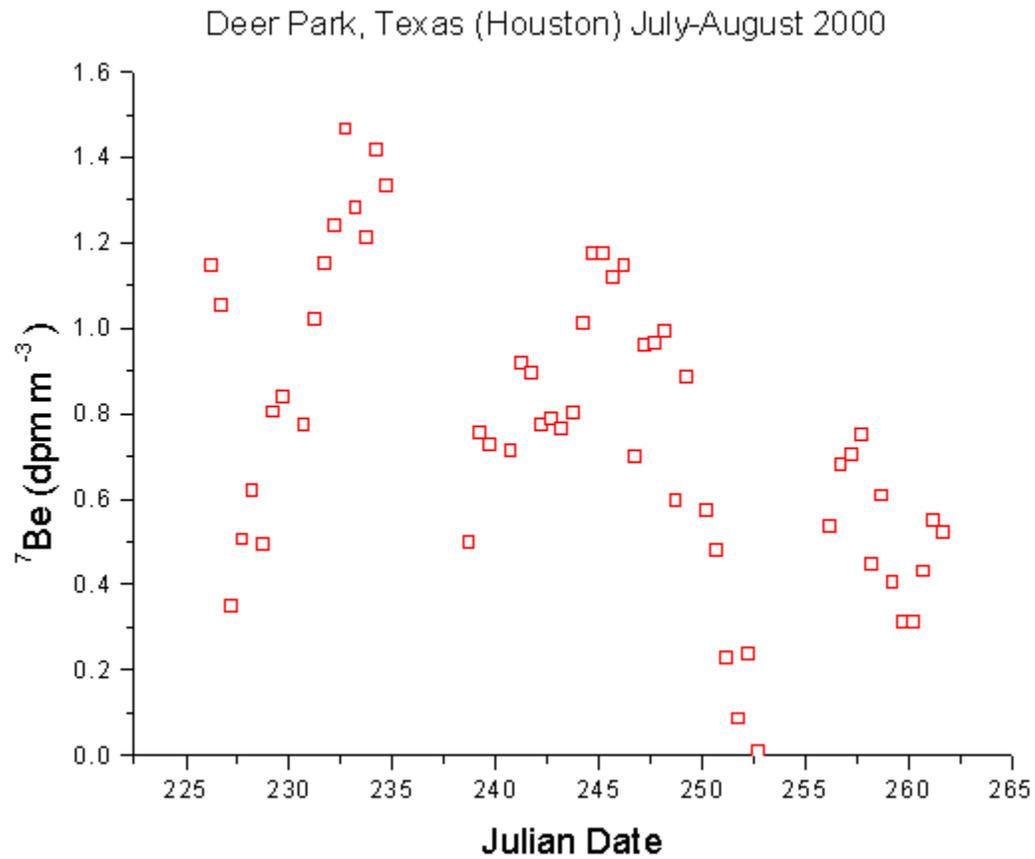


Figure 2. ^7Be data for Deer Park, Texas taken at 12 hour intervals during the Texas 2000 Air Quality Study.

PHOENIX 2001 Be-7 Dpm/m³ vs Julian Date

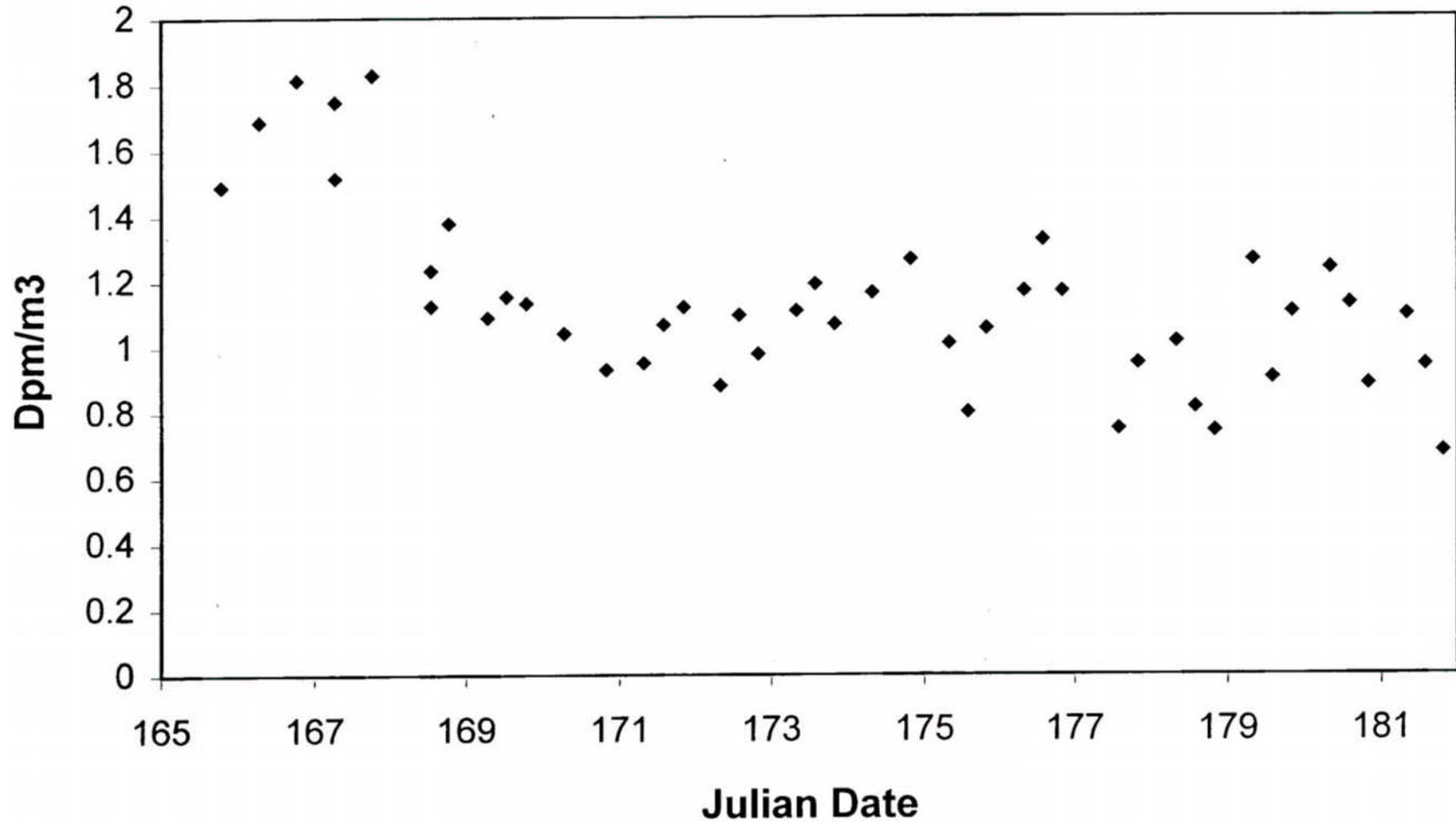


Figure 3. ⁷Be data from Phoenix, AZ samples collected at 6 and 12 hour intervals.

For the three sites, reasonably good agreement between the three sites was observed for the ^7Be levels. Concentrations of ^7Be in dpm m^{-3} in Pittsburgh were observed range from 0.08 to 0.31 during this period. This is very comparable to levels we observed in Houston during much of the study in 2000, and lower by a factor of 3-7 than values observed in the Phoenix area. The data do not indicate any significant “events” that would be interpreted as upper air mass transport into the Pittsburgh area during the sampling period. Computer modeling (IMPACT) by Lawrence Livermore National Laboratory has indicated that there may have been some downward transport during Phoenix 2001 as indicated by the higher ^7Be levels in the beginning of the sampling period (3).

Conclusions

High Volume Sampling and measurement of ^7Be can be readily done for aerosol samples. Sampling time periods of six hours or shorter are possible depending upon pumping speed used.

Gamma counting is non-destructive and can allow other chemical analyses to be conducted as well, after the counting. As anticipated, the ^7Be is a good tracer for fine aerosols. It is also a good indicator for upper air mass intrusions, which can be useful for addressing upper air mass downward transport and impacts into regional and urban air masses.

During the time the samples were collected minimal upper air intrusions from the mid- to upper troposphere were evident from the ^7Be data collected.

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