contrast to the direct incorporation of $CO_2$, the $NH_3$ produced by *P. SL-4* may first be converted, by way of a variety of nitrifying microorganisms, to nitrate. Nitrate may then be incorporated by plants, or the $NH_3$ may be incorporated directly without oxidation. *Pseudomonas SL-4* possesses the enzyme formamide amidohydrolase (E.C. 3.5.1.4), which performs reaction 1, and formate dehydrogenase (E.C. 1.2.1.2), which performs reaction 2. Since the nitrogen/carbon ratio is high in formamide, nitrogen is in excess. We have observed that formate does not accumulate and $CO_2$ and $NH_3$ are the major products.

$$HC(O)\text{–}NH_2 + H_2O \xrightarrow{\text{formamide amidohydrolase}} HCOOH + NH_3 \quad (1)$$

$$HCOOH + NAD^+ \xrightarrow{\text{formate dehydrogenase}} CO_2 + NADH + H^+ \quad (2)$$

where NAD is nicotinamide adenine dinucleotide and NADH is its reduced form.

*Pseudomonas SL-4* growing on formamide therefore occupies a position similar to that of organisms which hydrolyze urea (reaction 3) in that the same products are produced.

$$H_2N\text{–}C(O)\text{–}NH_2 + H_2O \xrightarrow{\text{urease}} 2NH_3 + CO_2 \quad (3)$$

While *P. SL-4* also possesses urease activity, it is incapable of growth on urea as the sole carbon, nitrogen, and energy source.

*Sorghum* has been shown to contain up to 1.6 m*M* cyanide as cyanogenic glycosides (*4*). Since fungal infection of *Sorghum* converts up to 90 percent of the cyanide present to formamide (*1*), significant quantities of formamide (1.4 m*M*) are available for utilization by *P. SL-4*. In addition to *Sorghum*, other cyanogenic plants have been shown to be infected by pathogenic fungi which convert cyanide to formamide (*3*). Since over 1000 species of cyanogenic plants have been demonstrated (*2*), significant quantities of carbon and nitrogen may be cycled in this manner.

The two major sources of nitrogen for mineralization are the proteins and nucleic acids of living organisms and the excretion of simple nitrogenous compounds (urea and uric acid) by animals (*5*). The nitrogen content of the first sources is liberated upon the death of the cells; proteins are hydrolyzed to amino acids and nucleic acids to purines and pyrimidines. These hydrolysis products are then further degraded to yield $NH_3$. In the cycle shown in Fig. 1, however, $NH_3$ is released by initial conversion of a plant product (cyanide) to formamide, followed by hydrolysis to yield the $NH_3$. In addition to the utilization of a product from a living plant, this cycle differs from that involving proteins and nucleic acids in that the compound involved in mineralization (formamide) is a single-carbon compound, as opposed to the multicarbon amino acids and nitrogenous bases involved above. Furthermore, the carbon-nitrogen compound is a microbial product, as compared with urea and uric acid, which are produced by higher organisms.

While quantitatively not as important as cycles involving urea, the formamide-mediated carbon-nitrogen cycle could be significant because of the large numbers of plants that produce cyanogenic glycosides.

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## Xenon-133: Ambient Activity from Nuclear Power Stations

Abstract. *The average activity of xenon-133 within and at approximately 100 kilometers from Albany, New York, from April to July 1975 was 2.6 picocuries per cubic meter of air. The source was gaseous effluents from boiling water reactors located in the northeastern United States. Its 5.29-day half-life makes xenon-133 an appropriate isotope to observe for the study of regional and hemispheric dispersion of pollutants.*

Although $^{133}Xe$ is an important gaseous radioactive fission product released in nuclear weapons tests and in the normal operation of the nuclear fuel cycle, it has usually been considered a local problem. With few exceptions, measurements of $^{133}Xe$ have been attempted primarily at the site boundaries of nuclear facilities. During 1964 and 1965, however, Scholch *et al.* (*1*) measured the activity of $^{133}Xe$ in atmospheric air samples taken from a location in West Germany. They observed an average activity of about 0.1 pc/m$^3$. The source for this activity was not evident. However, a maximum was obtained in June 1965, possibly attributable to a Chinese nuclear bomb test.

In 1975 we undertook to measure the average ambient background of $^{133}Xe$ in northeastern New York State and to determine the source of this activity. From April to July we collected samples at various locations within and at approximately 100 km from Albany (Fig. 1). The pattern was designed to ensure that the activity we were measuring was not from a local source, such as a hospital or laboratory using $^{133}Xe$, but was an ambient activity for this section of the state. Most of the sampling locations were 100 km or more from the nearest nuclear power reactor releasing $^{133}Xe$. Whereas samples in the West German study were obtained from an air liquefaction plant, our system permitted collection of grab samples at any desired location.

Air samples of 1 m$^3$ were collected with a portable air compressor and 15-liter stainless steel vessels containing 1 to 5 cm$^3$ of stable xenon carrier. The krypton and xenon fractions were separated from the samples by cryogenic adsorption and gas chromatography, as follows. The air sample in the high-pressure vessel was leaked at a reduced pressure of approximately 300 torr through a system containing three traps in series. The first trap, empty and at Dry Ice temperature, removed water vapor. The second trap, filled with glass beads and held at liquid nitrogen temperature, removed $CO_2$. The third trap, a column 1.5 m long and 1.25 cm in diameter filled with activated charcoal and maintained at liquid nitrogen temperature, retained the xenon and krypton. After the sample had been passed through, the charcoal-filled trap was warmed to 15°C, under vacuum, to remove most of the adsorbed nitrogen, oxygen, and argon. It was then heated to 200°C to drive off xenon and krypton, which were collected on a small molecular-sieve trap at liquid nitrogen temperature.

The krypton and xenon fractions are chromatographically separated and purified by using a column 4.6 m long and 0.63 cm in diameter filled with 94 percent type-5A molecular sieve and 6 percent

Fig. 1. Sampling area for $^{133}Xe$ survey. Marked sites are (•) sampling locations, (■) boiling water reactors, and (△) pressurized water reactors.

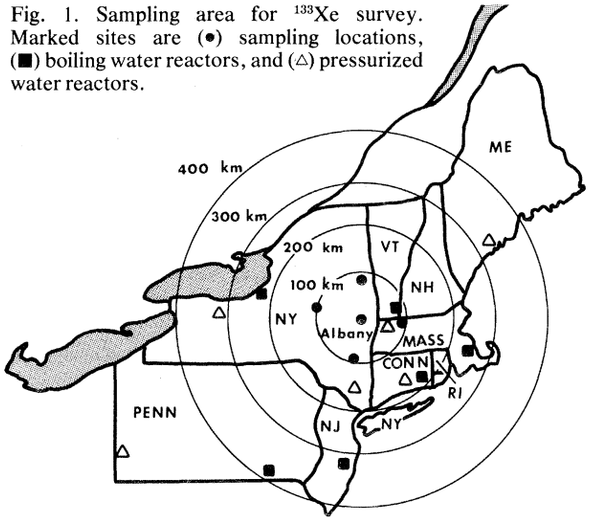


Table 1. Activity levels of $^{133}Xe$ and $^{85}Kr$ around Albany, New York, April to July 1975.

| Date collected | Location | Activity (pc/m³) | |
|---|---|---|---|
| | | $^{133}Xe$ | $^{85}Kr$ |
| 2 April | Albany | 0.52 ± 0.09 | |
| 2 April | Albany | 0.75 ± 0.11 | 16.7 ± 1.5 |
| 29 April | Albany | 4.4 ± 0.3 | 16.2 ± 1.3 |
| 29 April | Albany | 3.4 ± 0.3 | 16.3 ± 0.9 |
| 18 May | Albany | 3.9 ± 0.2 | 17.8 ± 1.5 |
| 18 May | Albany | 4.0 ± 0.2 | 18.4 ± 1.7 |
| 27 May | Little Falls | 1.32 ± 0.08 | 14.3 ± 1.4 |
| 4 June | Kingston | 3.18 ± 0.15 | 14.8 ± 1.2 |
| 11 June | Albany | 7.5 ± 0.2 | 14.8 ± 1.2 |
| 18 June | Greenfield, Mass. | 0.42 ± 0.05 | 17.2 ± 1.8 |
| 23 June | Albany | 1.29 ± 0.13 | 16.5 ± 1.0 |
| 24 June | Albany | 2.9 ± 0.3 | 16.5 ± 1.1 |
| 25 June | Albany | 0.32 ± 0.07 | 16.1 ± 1.2 |
| 7 July | Lake George | 2.37 ± 0.16 | 18.4 ± 1.0 |
| Average | | 2.6 | 16.5 |

activated charcoal. Mass spectrometric analysis has shown that the separated fractions contained less than 1 percent $N_2$ and He impurities. The separated fractions are loaded into gas-proportional detectors, the specific volumes are measured, and the recovery fraction of each is determined from the known carrier volume of xenon added or from the known abundance of krypton in air. Recovery fractions averaged 70 percent for each.

The counting system for $^{85}Kr$ has been described (*2*). The counting system for $^{133}Xe$ is a beta-gamma coincidence system with a 45-cm³ gas-proportional detector with thin aluminum walls and a 7.6 by 17.8 cm NaI(Tl) well detector. It includes a plastic scintillation anticoincidence cosmic-ray guard, with all components enclosed in a 15.2-cm-thick steel shield. The purified xenon sample is mixed with P-10 counting gas and loaded. The counting rates in the $^{133}Cs$ x-ray region and the 81-kev gamma-ray region of the photon spectrum are used to quantify the $^{133}Xe$. In the x-ray region the background is 0.018 count/min, and the efficiency is 0.26 count/min per disintegration per minute. Under the usual conditions of recovery and decay and for a 1-m³ sample volume, the detection limit, defined as 3 standard deviations over background (*3*), is 0.05 pc/m³.

Intermingled with the whole-air samples, 13 system blanks consisting of compressed, aged air were also processed. The results showed that the observed activities were not an artifact of the system. Spectral shapes and half-life measurements confirmed that the observed activity in the xenon fraction was due to $^{133}Xe$. All sample spectra had the same shape as that of a National Bureau of Standards $^{133}Xe$ standard, and the half-lives determined for several of the samples agreed with the 5.29-day half-life of $^{133}Xe$. Samples collected in duplicate, then processed and counted several days apart, were also in agreement.

An average ambient activity of 2.6 pc/m³ was obtained for $^{133}Xe$ (Table 1). The variation of the $^{133}Xe$ activities measured for all locations is consistent with values anticipated for regional sources, indicating that the levels obtained are not due to a local source but represent the ambient activity for this section of the Northeast. The observed average value of 16.5 pc/m³ for $^{85}Kr$ (Table 1) is in agreement with the values measured by the Environmental Radiation Ambient Monitoring System (*4*).

The observed levels of $^{133}Xe$ represent no significant health hazard at the present time. However, the genetically significant dose from $^{133}Xe$ is about three times greater than that from ambient $^{85}Kr$.

Nuclear power reactors are apparently the source of the $^{133}Xe$ activity. The interaction of cosmic rays with stable xenon cannot account for the observed levels, and there were no atmospheric tests for nuclear weapons during the 4 months when our measurements were made. The Soviet Union conducted two underground tests on 28 April and 10 June 1975. However, our findings before and after these tests show no indication that gaseous venting following these tests made a significant contribution of $^{133}Xe$ to the ambient level in the Northeastern United States. The locations of the operating nuclear power reactors within a radius of about 500 km from the sampling area are included in Fig. 1. Since boiling water reactors of current design release about two or three orders of magnitude more $^{133}Xe$ than the pressurized water reactors, they are evidently the predominant source of activity.

A regional dispersion model proposed by Machta *et al.* (*5*) for estimating long-term air concentrations was used to calculate an average expected value of $^{133}Xe$ from the six boiling water reactors shown in Fig. 1. We used their phase 2 equation, which estimates concentrations in the region at distances representing a few hours to several days' travel from the source, and assumed that the wind frequency is equal in all directions. In view of the geographic distribution of the sources relative to the sampling sites, we believe that any errors inherent in this assumption would tend to cancel out. We further assumed that each boiling water reactor releases $^{133}Xe$ at a rate of $6.4 \times 10^{-6}$ c/sec per megawatt (electric) capacity (*6*) and that each plant operates at 80 percent capacity. We also corrected for decay during diffusion. The calculated value of 3.3 pc/m³ is in good agreement with the observed average of 2.6 pc/m³, especially allowing for the approximations used in the calculation.

Models for estimating concentrations over a short period, such as a few hours, would require wind data monitored at a number of stations to determine wind trajectories, combined with measurements of the release rate of $^{133}Xe$ from all sources. This information was not available. The activity levels for 23, 24, and 25 June, however, do show the influence of weather patterns. On 23 and 24 June the Albany area was under an inversion layer that had originated to the southeast. During the night of 24 June a cold front moved through the area. On 25 June the area was under the

influence of a high-pressure system which had moved in from the northwest. The activity level decreased from 2.9 to 0.32 pc/m$^3$ after the weather front moved through.

Almost all the nuclear reactors currently in operation are located in the middle latitudes of the Northern Hemisphere. Dispersion of the effluent from these reactors is fairly rapid latitudinally and also vertically up to the mean mixing height. It takes about 30 days (*5*) for the effluent to travel around the earth, but in a matter of hours it reaches its mean mixing height, which varies from about 200 to 4000 m, depending on location, weather conditions, and season (*7*). Vertical dispersion above the mean mixing height and beyond the temperate latitudes proceeds more slowly, requiring 1 to 2 years for dispersion throughout the earth's atmosphere.

The half-life of 5.29 days for $^{133}$Xe is such that dispersion on a regional and hemispheric scale can be followed. Isotopes with significantly longer half-lives, such as $^{85}$Kr (10.76 years), accumulate throughout the atmosphere, making regional dispersion measurements difficult. Further measurements of ambient $^{133}$Xe could be correlated with more detailed information on the amount of $^{133}$Xe being discharged from the various sources and on the climatologic and geographic parameters. Such an approach would provide a more comprehensive model for estimating regional and hemispheric dispersion of all airborne pollutants, both radioactive and nonradioactive.

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## Lymphocyte-Induced Angiogenesis in Tumor-Bearing Mice

Abstract. *The presence of a growing tumor can lead to a significant curtailment of a graft-versus-host reaction as measured by the ability of allogeneic spleen cells to induce a host vascular response. This interference with the normal pattern of immunological reactions may be a reason for the survival of tumors in an immunologically alien environment.*

In describing the effect of intradermal transfer of immunocompetent lymphocytes on the host vascular system (*1*), we have called the host response—which is manifested by increased vascular tortuosity, visualization of more vessels, and histological changes reflecting endothelial cell differentiation—lymphocyte-induced angiogenesis (LIA).

At the same time, we remarked on the similarity between the vascular response induced by foreign lymphocytes and that induced by grafted tumor tissues (*1*). Subsequently we reported in more detail on that similarity (*2*). We now report on the effects of the presence of a growing tumor on the capacity of the host animal's vascular system to respond to the inoculation of foreign immunocompetent lymphocytes.

The methods used for induction and quantitative evaluation of the vascular response have been described (*1*). In brief, cell suspensions were prepared from spleens of normal mice of various strains, the concentration was adjusted so that an inoculum of 0.1 ml would contain $2 \times 10^6$ cells, and trypan blue was added to facilitate later visualization of the site of injection. Cells were injected intradermally into recipient tumor-bearing or control normal animals irradiated a few hours previously with x-rays (800 roentgens). After 2 to 3 days, the animals were killed with ether, the injection sites were exposed by dissection, and the number of scar-associated vascular branches was determined. We used the C57BL/6 C755 mammary carcinoma cells grown either in C57BL/6 or BDF$_1$ (C57BL/6 × DBA/2) hosts, while donor spleen cells were obtained from Ha/ICR (H2-q), CBA (H2-k), BALB/c (H2-d), and C57BL/6 (H2-b) strains of mice.

The results are shown in Fig. 1. As was expected, no vascular responses were seen in syngeneic combinations. In confirmation of our earlier work, $2 \times 10^6$ allogeneic spleen cells inoculated into irradiated normal recipients gave a typical vascular response (43 mice; the mean number of vessels was 22.3). In contrast, an equivalent number of allogeneic cells inoculated into mice bearing a large C755 mammary carcinoma elicited only a weak response (43 animals; the mean number of vessels was 8.6). Hosts with moderate tumors gave intermediate vessel counts (seven mice; the mean number of vessels was 11.0). Similar results have been obtained in preliminary experiments with line 129/J mice bearing OTT6050 teratoma.

We have no ready explanation for our

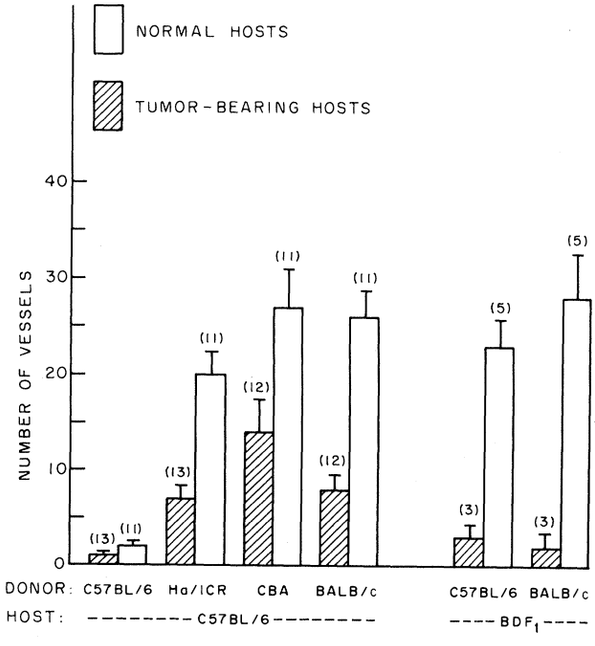


Fig. 1. Mean and standard error of extra blood vessels observed in lethally irradiated normal and tumor-bearing hosts in response to the intradermal inoculation of $2 \times 10^6$ allogeneic or semiallogeneic spleen cells; the number of host animals is shown in parentheses.