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ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY

1981

Prepared by the staff of the
Engineering and Technical Services Division
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

Editor: Gary E. Schleimer

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PREFACE

In 1976, R. H. Thomas published the LBL Annual Environmental Monitoring Report in two parts. Part I, LBL-4678, discussed in detail the modeling used to determine the population dose equivalent due to Laboratory operations. That volume also described natural radiation background, geological features, climate and meteorology, and the environmental surveillance program of the Lawrence Berkeley Laboratory. Part II, LBL-4827, included only the results of the sampling and measuring programs and other data necessary to determine the environmental impact of Laboratory operations for 1975. A format similar to LBL-4827 was used in the 1976, 1977, 1978, and 1979 Annual Monitoring Reports (LBL-6405, 7030, 9080, and 11192, respectively).

While the 1980 Annual Report, LBL-12604, was kept brief, abstracted sections from LBL-4678 were included so that the document might "stand alone." The same format has been used in this report.

Those readers wishing a more comprehensive discussion of LBL site characteristics and population dose modeling, may obtain a copy of LBL-4678 from:

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TABLE OF CONTENTS

ANNUAL ENVIRONMENTAL MONITORING REPORT OF THE LAWRENCE BERKELEY LABORATORY, 1981

ABSTRACT

The Environmental Monitoring Program of the Lawrence Berkeley Laboratory is described. Data for 1981 are presented and general trends are discussed.

INTRODUCTION

Lawrence Berkeley Laboratory (LBL) is a large, multifaceted research laboratory which conducts programs of pure and applied research in the physical, biological, and environmental sciences. LBL, birthplace of the cyclotron, celebrated its 50th anniversary in October 1981.

The Laboratory is located on the western slopes of coastal hills, east of the Berkeley campus of the University of California, between the 350- and 1,000-foot elevation contours. The site (Figs. 1 and 2) enjoys Mediterranean climate, an annual rainfall of 24.0 inches (23-year average), predominately northwesterly winds during traditionally dry summers, and southerly breezes during storms. LBL's hilly perimeter straddles two shallow canyons which contain the wellsprings of Strawberry and Blackberry creeks. The population within a 50-mile (80-km) radius of the Laboratory is approximately 4.6 million (1970 census); this includes most of the residents of the greater metropolitan San Francisco bay area.

LBL research facilities include: four large accelerators, several small accelerators, a number of radiochemical laboratories, and a tritium (^3H) labeling lab. The Bevatron (Building 51, Fig. 1) is the most massive of LBL's accelerators. Originally designed as a 6-GeV proton synchroton, the Bevatron is presently used to accelerate light- and medium-mass nuclei to energies up to 2 to 3 GeV per nucleon. The SuperHILAC (Building 71), a heavy-ion linear accelerator, is used to produce ion beams of energies up to 8 MeV per nucleon. A multi-programmable research accelerator in its own right, the SuperHILAC doubles as an injector for the Bevatron. The 88-inch Sector-Focused Cyclotron (Building 88) produces intense beams of light- and medium-mass nuclei to energies on the order of 100 MeV. The 184-inch Cyclotron (Building 6) provides alpha particle beams with energies up to ~1 GeV. The first three of the four accelerators described above provide beams for a variety of research applications around the clock; the 184-inch Cyclotron is run only for brief periods during the week and is operated mainly for tumor therapy.

The Tritium Facility located in Building 75 was designed to handle kilocurie quantities of tritium used as a labeling agent for a variety of molecules subsequently employed in chemical and biomedical research. Radiochemical and radiobiological studies performed in many laboratories at LBL typically use millicurie quantities of a variety of radionuclides. The workplaces and effluent release points of all installations at LBL where significant quantities of radionuclides are handled are continuously sampled.

1981 ENVIRONMENTAL MONITORING SUMMARY

In order to establish whether LBL research activities produced any impact on the population surrounding the Laboratory, a program of environmental air and water sampling and continuous radiation monitoring was carried on throughout the year.[1] For CY 1981, as in the previous several years, doses attributable to LBL radiological operations were a small fraction of the relevant radiation protection guidelines (RPG).[2]

The maximum dose delivered to a member of the community and the maximum fence-post dose were both $\leq$ 15.1 mrem (the 1981 dose equivalent measured at the Building 88 monitoring station B-13A, about 3.0% of the RPG). The total population dose equivalent* attributable to LBL operations during CY 1981 was $\leq$ 10.0 man-rem, about 0.0013% of the RPG of 170 mrem/person to a suitable sample of the population.

The People's Republic of China conducted an atmospheric nuclear test on or about October 15, 1980. From January through August 1981, slightly elevated levels of gross-beta activity were found in weekly environmental air samples. Gamma analysis of the samples revealed small quantitites of mixed fission fragments and activation products, predominately ^{95}Zr/Nb, ^{106}Rh, ^{141,144}Ce, ^{137}Cs, and ^{54}Mn. Maximum concentration of the fission products reached 0.47×10^{-12} μCi/ml (maximum activity was found on samples removed March 24, 1981).

* Defined as the sum of the doses delivered to all individuals residing within an 80-km radius of LBL.

ENVIRONMENTAL MONITORING RESULTS

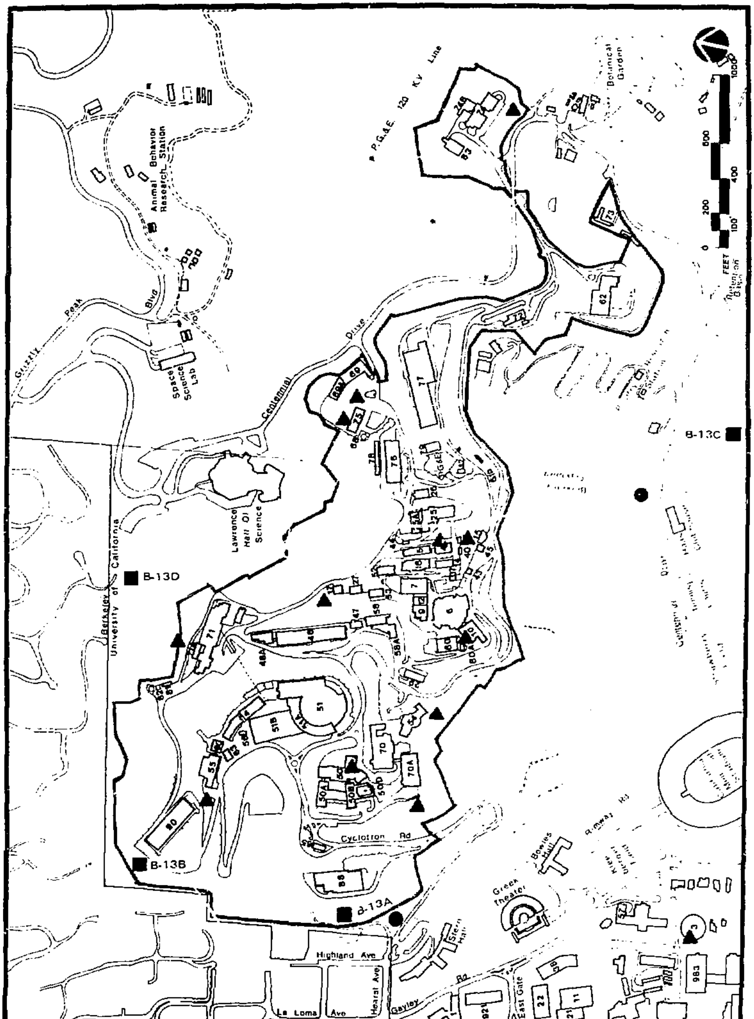
ACCELERATOR-PRODUCED RADIATION

To determine the radiological impact of LBL accelerator operations, we maintain permanent monitoring stations at four points about LBL's perimeter (see Fig. 1 and Table 1).

Table 1. Location of LBL monitoring stations.

Fig. 1 Bldg. Designation	"Common Name"
B-13 A	Bldg. 88 Environmental M. S.
B-13 B	Bldg. 90 Environmental M. S.
B-13 C	Panoramic Environmental M. S.
B-13 D	Olympus Gate Environmental M. S.

Each station contains sensitive neutron and gamma pulse counters. The neutron detectors are ~500-cm^3 cylindrical BF_3 chambers housed in 2.5-in.-thick cylindrical paraffin moderators. The gamma detectors are energy-compensated Geiger-Muller chambers. The output pulses from each of the eight detectors (one of each type is installed at each monitoring station) are prescaled and telemetered to registers in Building 75.[4] Each LBL accelerator building contains at least one somewhat smaller moderated BF_3 neutron detector whose output pulses are also prescaled and telemetered to Building 75. Operational checks of the system are performed daily, and detectors are calibrated semiannually. Typical dose per register-pulse value for a perimeter monitoring station neutron detector is 0.43 μrem/pulse. A gamma register-pulse is about 1.3 μR.



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■ PERIMETER STATIONS
▲ OTHER ATMOS. SAMPL'G SITES
● SEWER SAMPLERS

FIGURE 1

The neutron background attributable to cosmic rays measured at LBL exhibits small fluctuations about a mean value of 3.3 mrem/year.[3] Table 2 lists the fence-post doses measured at each environmental monitoring station during 1981.

The fence-post neutron fluence and gamma ray flux attributable to LBL accelerator operation for 1981 is characterized as follows:

1. The 184-inch cyclotron produced a dose of $\leq$0.1 mrem, as measured at the Panoramic M. S. (Table 2).

2. The SuperHILAC and Bevatron contributed equally to the dose measured at the Olympus Gate M. S., a dose distributed rather uniformly from January to early July.

3. The 88-inch Cyclotron dose was distributed rather uniformly throughout the year and may be divided into two operating categories:

   a. A fence-post dose of 11.2 mrem due to neutron fluence and 0.5 mrem due to gamma flux produced during 52 short, intense light-ion (D^+, p^+, $^3He^+$) runs that were conducted once or twice a week throughout the operational year.

   b. During the remainder of the operational year, a 3.4-mrem neutron dose was produced by all other work.

4. The Building 90 M. S. dose is correlated with and attributed to 88-inch Cyclotron operations.

The continuous gamma measurements telemetered from the Building 90 and Olympus Gate monitoring stations showed no significant correlation with the operation of any of the LBL accelerators and were background for 1981. The mean value of gamma background was 80 ± 5 mrem for the year. The gamma channel from the Panoramic M. S. failed to produce consistently reliable data in 1981 and is not reported here.

Table 2. Radiation dose at the LBL boundary due to accelerator operation, 1981.

Station	1980 Total above background		
	γ (mrem)	n (mrem)	Total[a] (mrem)
Olympus Gate M. S.	Background	5.0 ± 0.11	5.0 ± 0.11
Building 90 M. S.	Background	0.2 ± 0.1	0.2 ± 0.1
Building 88 M. S.	0.5 ± 0.1	14.6 ± 0.18	14.6 ± 0.18
Panoramic M. S.	----------	0.1 ± 0.1	0.1 ± 0.1
Standard for comparison (Dose to individuals at the maximum point of exposure)		500[b]	

[a]The errors shown are those associated with the actual counts. Dose conversion factors are not known to this accuracy.

[b]Source: Reference 2.

AIRBORNE RADIONUCLIDES

Gross atmospheric beta and alpha activities are measured by air sampling at 14 points--4 perimeter environmental monitoring stations and 10 of the 12 other atmospheric sampling sites identified in Figure 2. (The sites on the north side of Building 75 and the roof of Building 4 are rain collectors; the Building 3 site contains samplers for HTO[tritriated water] and $^{14}CO_2$).

The gross beta and alpha sampling media are 4-in. by 9-in. cellulose-asbestos filters through which air is pumped at 4 cfm. Samples are changed weekly. Before they are counted, they are set aside for five days to enable short-lived radon and thorium daughters, naturally occurring airborne radionuclides, to decay. The filters are loaded into an automatic

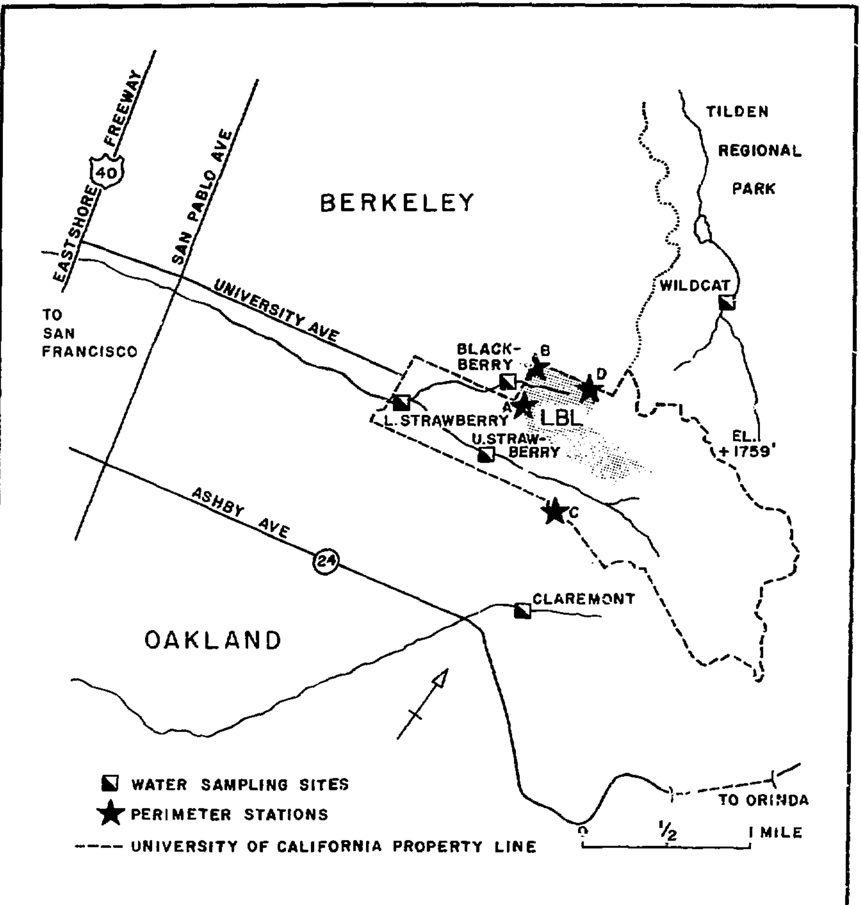

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FIGURE 2

counter, which determines their gross-alpha activity by means of a large-area, 0.25-mil-mylar-window, gas-proportional counter. Gross-beta is counted with Geiger-Muller detectors with 30-mg/cm^2 windows. The detection limit for alpha emitters is 2×10^{-15} µCi/ml; the limit for beta emitters is 80×10^{-15} µCi/ml.

To assure accuracy of all counting results, each group of samples counted includes at least one radiation standard sample and a number of background samples.

Tritium, as HTO, is sampled by passing atmospheric air through a column containing silica gel. Adsorbed water is "exchanged" into distilled water and an aliquot (5 ml) is placed in a vial and counted in a scintillation counter. The detection limit for HTO in air is 700×10^{-12} µCi/ml.

As with gross alpha and beta samples, silica gel HTO samples are changed weekly. Each of the four perimeter environmental monitoring stations contains a tritium sampler, as does the Building 3 site. The stack from the tritium labeling facility is also monitored for tritium as described above.

The concentration of $^{14}CO_2$ in air is determined by air sampling with NaOH; samples are changed weekly. Air is bubbled through a jar containing 30 ml of 0.2 M NaOH and thymol blue as a pH indicator. If acid fumes in the sampled air drop the pH of the sample to about 5, a color change results, and the sample is assumed to be invalid. An aliquot (5 ml) of the NaOH is added to scintillation cocktail and counted in a liquid scintillation counter. The detection limit for $^{14}CO_2$ is 200×10^{-12} µCi/ml.

The total quantitites of radionuclides discharged into the atmosphere are summarized in Table 3. The figures are similar to those of last year, and the releases resulted in a small population dose equivalent (see Table 11).

Table 3. Total quantities discharged into the atmosphere, 1981.

Nuclides	Quantity Discharged (Ci)
Unidentified α emitters	$< 1 \times 10^{-6}$
Unidentified beta-gamma emitters	4.1×10^{-5}
Carbon-14	0.039
Tritium	70
Iodine-125	5.6×10^{-4}

All data from the general air sampling program were within the range of normal background (Table 4). All measurements of atmospheric deposition at perimeter stations lie within the range of normal background, although small amounts of tritium were detected in rainfall collected within the Laboratory boundary (Table 5).

The special air sampling program for ^{14}C and ^{3}H found detectable concentrations of these nuclides (Table 6). Essentially, 100% of the tritium released from LBL was discharged from the Building 75 stack.

Table 4. Summary of air samples, 1981.

	No. of samples	Concentration, 10^{-15} μCi/ml						Average as % of standard	
		Alpha			Beta			Alpha	Beta
		Avg.	Min.	Max.	Avg.	Min.	Max.		
On-site average of 10 locations	492	0.57 ± 0.10	<2	5	92 ± 4	<80	390	3	0.9
Perimeter Stations									
Bldg. 88	47	1.14 ± 0.31	<2	5	100 ± 13	<80	460	6	1.0
Bldg. 90	48	1.09 ± 0.30	<2	5	120 ± 13	<80	350	6	1.2
Panoramic Way	50	1.20 ± 0.30	<2	5	140 ± 12	<80	470	6	1.4
Olympus Gate	50	0.89 ± 0.29	<2	4	120 ± 12	<80	370	4	1.2
Standard for comparison[a]		20			10,000				

[a]Source: Reference 2.

Table 5. Summary of atmospheric deposition, 1981.

	Total deposition, 10^{-3} $\mu Ci/m^2$						Tritium in rainfall, $\mu Ci/m^2$ (as HTO)[a]		
	No. of samples	Alpha		Beta			No. of samples	Avg.	Max.[b]
		Avg.	Max.[b]	Avg.	Min.	Max.[b]			
On-Site (9 locations)	108	<0.01	<0.03	5.3	4.3	6.6	174	0.5 ± 0.07	8.6 ± 0.7[c]
Perimeter (4 locations)	48	<0.01	0.09	6.9	5.2	9.7	36	<0.1	<0.2

No standards for comparison have been established

[a]The on-site tritium-in-rainfall data are computed from samples taken at 11 locations.

[b]Highest total for any one site.

[c]Although "on-site", this location is near the fence and representative of the area just outside the perimeter. The average tritium-in-rainfall concentration at this location (Bldg. 75 collector) was 11×10^{-6} μCi/ml, 0.4% of the drinking water concentration guide (CG); the maximum observed concentration was 83×10^{-6} μCi/ml or 3% of the guideline (Ref. 2).

Table 6. Summary of special air sampling, 1981.

	No. of samples	Concentration, 10^{-9} μCi/ml			Average as % of standard
		Avg.	Min.	Max.	
Samples for Tritium as HTO					
On Site					
Bldg. 3 roof	50	<0.2	<0.7	<0.7	< 0.1
Perimeter					
LHS	50	<0.2	<0.7	1.1	< 0.1
B-13D (Olympus)	50	<0.2	<0.7	0.7	< 0.1
Standard for Comparison[a]		200			
Samples for Carbon-14 in Air (as CO_2)					
On-Site					
Bldg. 3 roof	50	<0.06	<0.2	0.2	<0.006
Standard for Comparison[a]		1000			

[a]Source: Reference 2.

WATERBORNE RADIONUCLIDES

Rainwater, creek water, and sewage from LBL's two sewer outfalls are analyzed for gross beta and alpha (Fig. 1 - the Strawberry sanitary sewer is the southern site; Hearst is the western sewer). Additionally, sewer effluent is analyzed for gross halogen (radioiodine) content; rainwater is analyzed for tritium (the Building 75 tritium labeling facility does not release liquid effluent into the sewer or surface streams).

Sewer outfalls are sampled continuously, sample-to-flow ratios are designed to be between 10 and 20 parts per million, and composite samples are removed weekly. The five creek-sample points indicated in Figure 2 are sampled weekly. A one-quart "grab" sample is taken from each site and analyzed for gross alpha and beta only.

The four perimeter environmental monitoring stations have 18-inch-diameter cylindrical rainfall collectors on their roofs. During rainy months (generally October through May), rainwater is picked up monthly and analyzed for gross beta and alpha and for tritium. During the dry California summer, each collector is rinsed with a quart of tap water, and the rinse is analyzed for "dry deposition." The ten "other atmospheric sampling sites," alluded to in the air sampling section of this report, each contain an 18-inch-diameter combination, rain/dry deposition collector, which is sampled on a monthly basis in the same manner as the four perimeter environmental monitoring stations.

Rain which falls into the collector on the north side of Building 75 is analyzed on a storm-by-storm basis for tritium, gross alpha, and gross beta. Tritium analysis of water samples is accomplished by liquid scintillation counting. Water samples are prepared for gross alpha and beta analysis by acidification (HNO_3) and evaporation into 2-inch stainless steel planchettes. Organic residues not "wet ashed" by the nitric acid treatment are oxidized by flaming of the planchettes.

Since radioiodine is driven out of the water samples when they are acidified, aliquots of the sewer effluent samples are preserved for radioiodine analysis. The iodine contained in the samples is precipitated with silver using stable KI as a carrier. The iodine aliquots are filtered, and the filtrate is processed in the same manner as the acid (HNO_3) samples described earlier. After flaming the filtrate planchette, the filter containing any precipitated radioiodine is placed in the planchette and counted.

The prepared planchettes are weighed (each planchette is "tared" before sample processing) and counted in an automatic thin-window, low-background, gas-proportional counter for both gross beta and alpha. Since the samples are "thick," self-absorption is computed based upon areal sample density, which is the sample weight divided by 20.26 cm^2, the area of the planchette (assuming an alpha energy of 5.2 MeV and beta energy of 1 MeV).

Table 7 summarizes the 1981 data from the surface water and tap water sampling programs. These results are similar to those obtained in past years, and all lie within the normal range of background activity. There is no reason to suspect that any of the observed radioactivity originated from the laboratory.

Table 7. Surface water and tap water samples, 1981.

	No. of samples	Concentration, 10^{-9} µCi/ml						Average as % of standard	
		Alpha			Beta			Alpha	Beta
		Avg.	Min.	Max.	Avg.	Min.	Max.		
On-Site Streams									
Blackberry	50	<0.2	<0.7	3.0	3.3 ± 0.1	<1	45	<0.7	3.3
Lower Strawberry	50	<0.3	<0.7	1.0	3.7 ± 0.1	<1	24	<1	3.7
Upper Strawberry	50	<0.3	<0.7	2.0	2.3 ± 0.1	<1	19	<1	2.3
Average		<0.2			3.1 ± 0.1			<0.7	3.1
Off-Site Streams									
Claremont	50	<0.3	<0.7	2.8	2.1 ± 0.1	<1	22	<1	2.1
Wildcat	50	<0.3	<0.7	1.7	1.0 ± 0.1	<1	3	<1	1.0
Average		<0.2	<0.7		1.6 ± 0.1			<1.7	1.6
Tap Water	50	<0.1	<0.7	0.4	0.96 ± 0.01	<1	1.6	<0.3	1.0
Standard of Comparison[a]			30		100				

[a]Source: Reference 2.

Table 8 summarizes the sewage sampling data for 1981. The average and maximum values listed for sewer beta concentrations reflect the weekly activity found in the hotter of the acid or radioiodine planchettes. LBL's historical release practices were maintained during 1981, and the Hearst sewage average beta concentration was about 0.7% of the DOE standard for beta discharges to sewers.[2] The campus of the University of California discharges radioactive waste into the Strawberry sewer above the point at which LBL monitors it. While the average Strawberry beta concentration for 1981 was significantly higher than the Hearst value, the amount is well below historical values and is about 8% of the standard (1979 average Strawberry beta concentration was 86% of the standard).

NONRADIOACTIVE POLLUTANTS

The Laboratory does not carry out routine monitoring of airborne nonradioactive pollutants, although sewer sampling is carried out for heavy metals. The analysis is achieved by atomic absorption.

From January through May 1981, the samples were analyzed at LBL. Subsequently, samples were analyzed at Lawrence Livermore National Laboratory.

Table 9 summarizes the sewer sampling data for heavy metals.

Table 8. Summary of sewage sampling data, 1981.

Total Quantities Discharged	Total Volume (10^6 liters)	Alpha (μCi)	Beta (mCi)
Hearst Sewer	281	<55	5.9
Strawberry Sewer	89	44	21.4
Total	370	<99	27.3

Net Concentrations	No. of samples	Concentration, 10^{-9} μCi/ml						Average as % of standards	
		Alpha			Beta			Alpha	Beta
		Avg.	Min.	Max.	Avg.	Min.	Max.		
Hearst	49	<0.2	<0.4	1.1	21	<6	150	<0.05	0.7
Strawberry	43	0.5	<0.4	14	240	8.1	2500	1.2	8.0
Overall		<0.27			74			<0.07	2.5
Standard for Comparison[a]		400			3,000				

[a]Source: Reference 2.

Table 9. Summary of sewer sampling data for heavy metals, 1981.

		Metals detected							
	No. of Samples	Chromium	Copper	Zinc	Silver	Cadmium	Nickel	Iron	Lead
Standard for comparison									
EBMUD[a] limitation on discharge (mg/l)		2	5	5	1	1	5	100	2
Hearst Sewer									
Average (mg/l)	47	0.91	2.16	1.26	<0.1	<0.1	0.13	5.1	0.35
% of standard		46	43	25	<10	<10	2.6	5.1	18
Strawberry Sewer									
Average concentration (mg/l)	36	1.52	17.8	7.72	<0.1	<0.1	0.50	51	3.53
% of standard		76	356	154	<10	<10	10	51	176

[a]East Bay Municipal Utility District.

POPULATION DOSE RESULTING FROM LBL OPERATIONS

ACCELERATOR-PRODUCED RADIATION

The LBL model for determining population dose equivalent from the maximum measured value of fence-post dose developed by Thomas[3] assumes that the fence-post dose is uncorrelated with fluctuations in population. During 1981, the maximum fence-post dose was measured at the Building 88 monitoring station and was 15.1 mrem for the year (Table 2). The 88-inch Cyclotron operated continuously during 1981 except for weekly maintenance periods, a summer shutdown from June 15 to July 22, and a Christmas shutdown from December 16 to the end of the year. Dose "spikes" attributable to short, intense light ion runs were distributed throughout the operational year. Although the shutdown periods occurred when student/faculty populations were low (summer and Christmas vacations) and the shutdown time represents about 14% of the year, the model's assumptions should not be seriously compromised by ignoring these non-uniformities.

The model's expression relating population dose equivalent M (in man-rem) to the maximum measured fence-post dose H_0 (in rem) is:

$$M \leq 10^3 \cdot H_0(1.0-0.56f) \tag{1}$$

(where f = the fraction of the fence-post dose contributed by the 88-inch Cyclotron and/or the SuperHILAC compared to the dose contributed by the Bevatron).

Figure 1 shows that the Bevatron is equidistant from the Olympus Gate and Building 88 environmental monitoring stations. It is reasonable to assume that the fence-post dose attributable to the Bevatron as measured at the Olympus Gate station would be the same dose measured at the Building 88 monitoring station if both stations were within line of sight of the Bevatron. However, LBL's hilly contours block the line of sight from the Bevatron to the Building 88 monitoring station. Because the Bevatron contributed 2.5 mrem to the fence-post dose at the Olympus Gate station (one-half of the 5.0 mrem measured at that station), we establish the value of f in Equation (1) in in the following manner:

$$f = \frac{15.1 \text{ mrem}}{15.1 \text{ mrem} + 2.5 \text{ mrem}} \qquad (2)$$

$$f = 0.86$$

Substituting this value of f in Equation (1) and using the H_0 measured at the Building 88 monitoring station, we find the population dose attributable to accelerator operation to be:

$$M \leq 10^3 \times 0.0151[1.0 - 0.56(0.86)] \text{ man-rem}$$

$$M \leq 7.8 \text{ man-rem for 1981} \qquad (3)$$

AIRBORNE RADIONUCLIDES

The population dose equivalent resulting from airborne releases of radioactive nuclides can be determined from the model developed by Cantelow.[3] To provide more consistent reporting of these data, new values have been calculated for the constant, R (man-rem per curie released). These values, shown in Table 10, are based on Maximum Permissible Concentration (MPC) data listed in Ref. 2. These values replace those listed in Ref. 3, Table 16. Table 11 summarizes the total population dose equivalent due to LBL operations.

Table 10. Population dose equivalent resulting from the release of one curie of radionuclides.

Nuclide	MPC[a] (μCi/ml)	R[a] (rem $m^3 Ci^{-1} s^{-1}$)	α_R[a] (man-rem/Ci)
Unidentified α emitters	2×10^{-14}	7.9×10^5	3×10^5
Unidentified β emitters	1×10^{-11}	1.6×10^3	7×10^2
^3H	2×10^{-7}	0.079	0.03
^{14}C	1×10^{-6}	0.016	0.007
^{125}I	8×10^{-11}	200.0	80.0

[a]Source: Reference 2.

Table 11. Population dose equivalent, 1981.

Contributing Factor	Population Dose (man-rem)
Penetrating radiation from accelerator operation	7.8
Radionuclide release:	
^3H	2.1
^{14}C	0.003
^{125}I	0.04
Unidentified Alpha emitters	<0.03
Unidentified Beta emitters	0.03
Total	10.0

For 1981, the population dose attributable to natural background sources for the population within 80 km of LBL was approximately 4.6×10^6 persons x 0.083 rem/person-yr = 3.8×10^5 man-rem.

TRENDS - LBL ENVIRONMENTAL IMPACT

ACCELERATOR-PRODUCED PENETRATING RADIATION

Figures 3-6 show the annual accelerator-produced dose equivalent reported by the four perimeter environmental monitoring stations from the year they were established to date. During the past several years, the LBL accelerators have run heavy ions during an increasing fraction of their operating schedule. Successful work in beam development has served to increase beam currents in recent years. However, concomitant improvements in beam optics have minimized stray radiation losses along the beam transport lines, resulting in small annual population doses.

AIRBORNE AND WATERBORNE RADIONUCLIDES

With the exception of occasional known releases, the atmospheric sampling program has yielded data over the past few years which are within the range of normal background. The surface water program always yields results within the range of normal background. Because no substantial changes in the quantities of radionuclides used are anticipated, no changes are expected in these observations. Under the terms of its license, the University of California Berkeley campus has historically discharged radionuclides into the Strawberry sewer, complicating the analysis of LBL sewer sampling data. U.C. discharge practice, curtailed during 1979, is expected to remain modest.

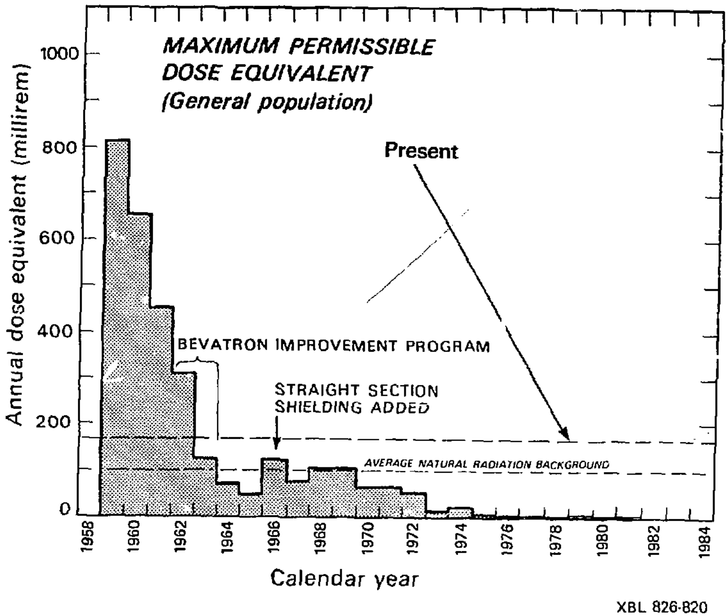

Figure 3. Annual accelerator-produced dose equivalent reported by the Olympus Gate environmental monitoring station.

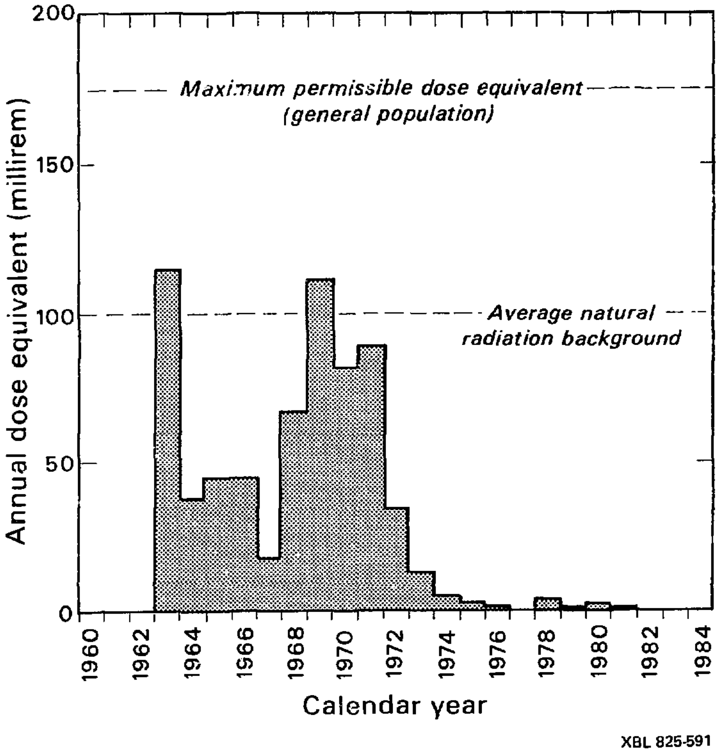

Figure 4. Annual accelerator-produced dose equivalent reported by the Building 90 environmental monitoring station.

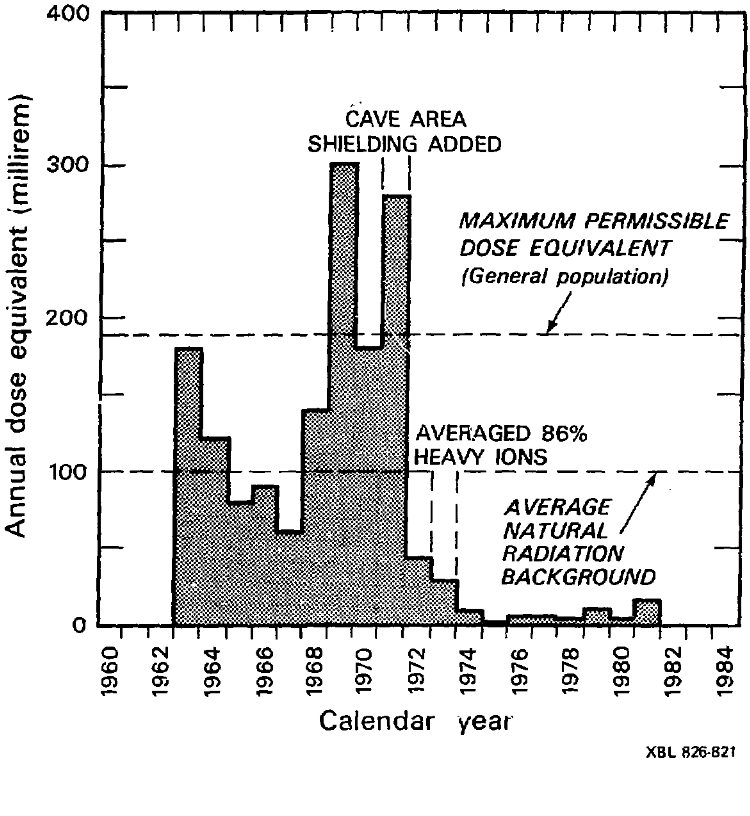

Figure 5. Annual accelerator-produced dose equivalent reported by the 88-inch Cyclotron environmental monitoring station.

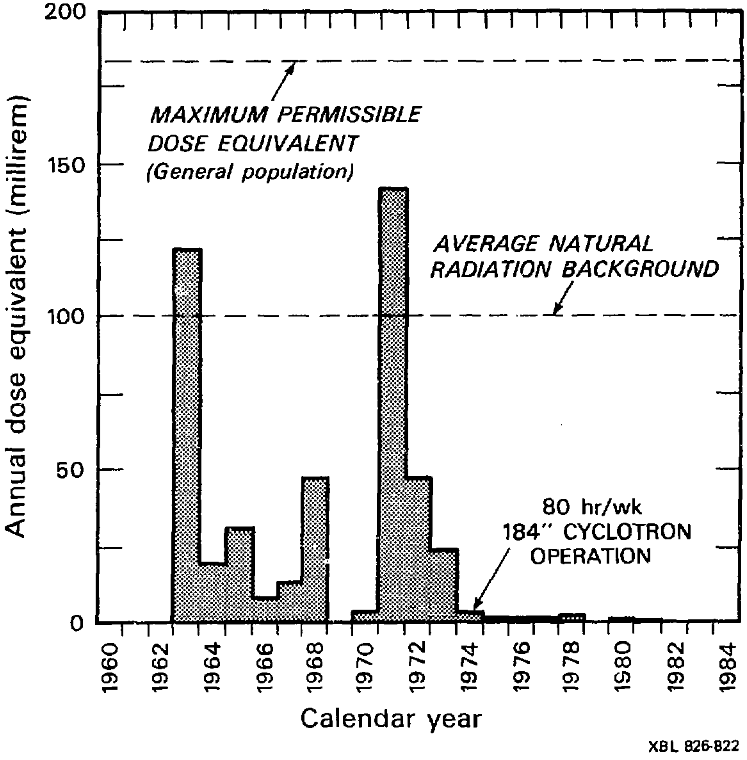

Figure 6. Annual accelerator-produced dose equivalent reported by the Panoramic Way environmental monitoring station.

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