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1963 ENVIRONMENTAL RADIATION LEVELS AT BROOKHAVEN NATIONAL LABORATORY

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PREFACE

Environmental monitoring data have been obtained in the vicinity of Brookhaven National Laboratory since 1949. Except for the limited amount appearing since 1960 in semiannual press releases, little of this information was available in report form prior to 1962.

Following the resumption of atmospheric testing of nuclear devices in the latter part of 1961, considerable data have been obtained on fallout levels in the environment. To make these data generally available to interested persons, most of the environmental monitoring data for 1962 were summarized in a report.[1] The present report contains similar information for 1963.

1963 ENVIRONMENTAL RADIATION LEVELS AT BROOKHAVEN NATIONAL LABORATORY

INTRODUCTION

The evaluation of prevailing radiation levels in the vicinity of the Brookhaven National Laboratory site is performed by the Environmental Monitoring Section of the Health Physics Division. Laboratory operations contribute three principal additions to the natural background radiation in the vicinity: the gaseous and particulate radioactivity contained in the cooling-air effluent of the Brookhaven Graphite Research Reactor (BGRR) and the Medical Research Reactor (MRR); radiation from two multicurie field gamma sources; and the low levels of radioactivity contained in liquid wastes released to a small stream that forms one of the headwaters of the Peconic River.

Natural background and radiation levels attributable to Laboratory operations during 1963 are summarized in this report.

Record amounts of fallout, principally from the atmospheric testing of nuclear weapons by the USSR during the latter part of 1962, were also observed in many types of environmental samples. Although the identification of fallout has been an incidental aspect of the Environmental Monitoring Section's activities, the information obtained on fallout radioactivity levels is also summarized.

Among the data reported are external whole-body exposures, air particulate concentrations, rain and settled dust collections, milk and vegetation concentrations, and liquid effluent and off-site stream concentrations.

EXTERNAL EXPOSURE MONITORING

Environmental radiation levels, including natural background (as influenced by fallout) and the increments attributable to the BGRR and MRR cooling-air effluent and the ecology forest sources, were monitored continuously at eight fixed area-survey stations. As indicated in Figure 1, three of these stations are on site, four are on or near the perimeter, and one is off site. A second off-site station, O-1, previously maintained $\approx$4 miles south of the BGRR stack, was discontinued during 1963. Included in the equipment at each station is an ion chamber and dynamic condenser electrometer assembly, which has been described in detail elsewhere.[2] These units are capable of accurately measuring $<10\ \mu$R/hr and of detecting changes of the order of 1μR/hr. Although information about the instantaneous dose-rate up to $\approx$0.5 mR/hr may be obtained from these units, normally the integrated radiation over 4-hr periods is used to obtain weekly averages, which are in turn used to compute the monthly data tabulated in this section.

Monthly average gross external radiation levels are set forth in Table 1. For convenience in making

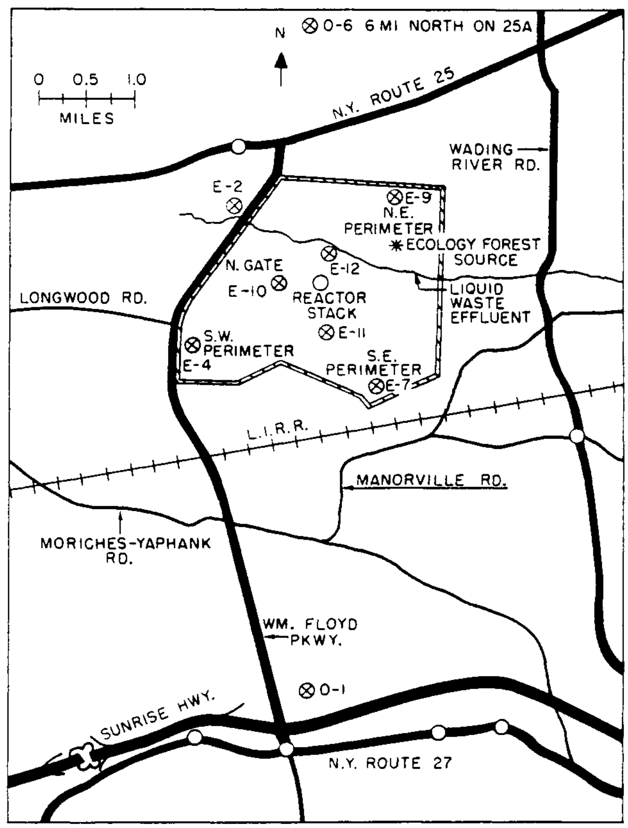

Figure 1. Location of BNL environmental monitoring stations.

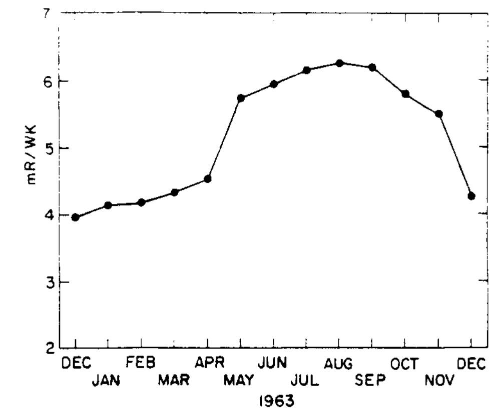

Figure 2. Natural background radiation levels, composite monthly average.

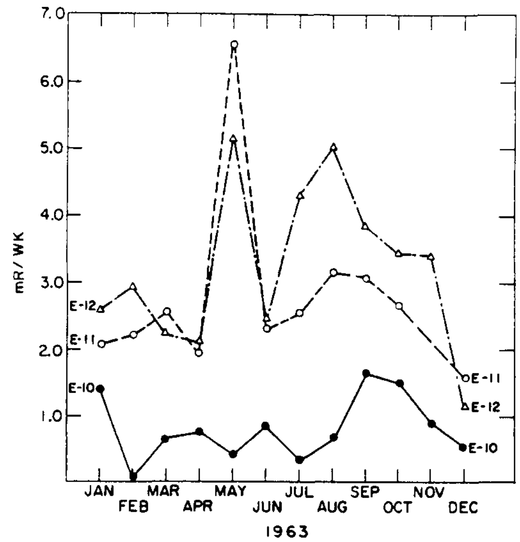

Figure 3. Monthly average Ar^{41} radiation levels, on-site stations.

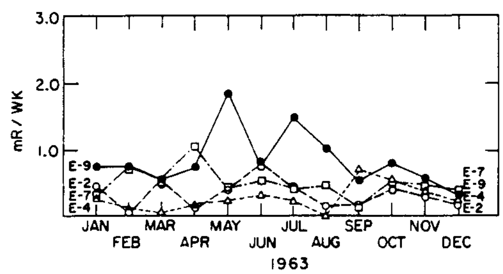

Figure 4. Monthly average Ar^{41} radiation levels, perimeter stations.

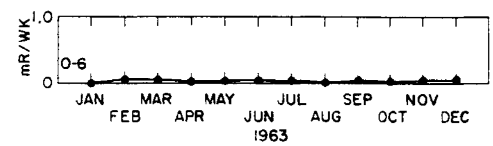

Figure 5. Monthly average Ar^{41} radiation levels, off-site station O-6.

Table 1

1963 BNL Environmental Monitoring
Monthly Average Gross Radiation Levels, mR/wk

	On site			Perimeter				Off site	
Month	E-10	E-11	E-12	E-2	E-4	E-7	E-9	O-1	O-6
Jan.	6.08	6.05	6.93	4.74	4.27	4.23	6.83	4.05	3.58
Feb.	5.24	6.49	7.05	4.08	4.03	4.65	6.58	4.69	3.25
Mar.	5.79	7.06	6.95	4.79	4.05	4.68	6.79	4.28	3.45
Apr.	6.10	6.77	7.14	4.70	4.18	5.63	7.48	4.47	3.77
May	7.48	12.52	11.07	5.99	5.27	5.85	9.44	9.62	4.56
June	8.20	8.05	8.80	6.82	5.53	6.22	9.33	5.33	4.71
July	7.77	8.51	10.60	6.74	5.77	6.30	10.51	5.73*	5.12
Aug.	8.07	9.13	11.60	6.46	5.68	6.34	9.36		6.15
Sept.	9.37	8.98	9.99	6.47	6.53	6.09	8.44		6.04
Oct.	7.34	8.15	9.55	6.64	6.14	6.02	8.38		5.79
Nov.	6.23	7.59	9.36	6.18	5.71	5.46	8.02		5.54
Dec.	3.27	6.00	5.71	4.78	4.76	4.92	6.18		3.63
Av	6.74	7.94	8.72	5.70	5.17	5.53	8.10	5.45	4.63

Estimated error at 90% confidence level, ±0.30 mR/wk. *Station O-1 discontinued July 16, 1963.

Table 2

1963 BNL Environmental Monitoring
Monthly Average Background Radiation Levels, mR/wk

	On site			Perimeter				Off site	
Month	E-10	E-11	E-12	E-2	E-4	E-7	E-9	O-6	All stations, av
Jan.	4.62	4.27	4.10	4.31	4.01	3.96	4.50	3.36	4.14
Feb.	5.18	4.27	3.89	4.03	3.92	3.89	4.36	3.78	4.17
Mar.	5.11	4.48	4.43	4.22	4.00	4.12	4.50	3.71	4.32
Apr.	5.32	4.83	4.26	4.57	3.99	4.55	4.97	3.78	4.53
May	7.00	6.37	5.55	5.56	5.03	5.45	6.16	4.55	5.71
June	7.35	5.74	6.03	6.00	5.22	5.65	6.69	4.69	5.92
July	7.47	5.95	5.96	6.27	5.50	5.88	6.95	5.04	6.13
Aug.	7.42	5.95	6.23	6.29	5.67	5.85	6.23	6.09	6.22
Sept.	7.75	5.92	5.82	6.34	5.83	5.83	5.99	6.02	6.19
Oct.	5.84	5.47	5.78	6.23	5.57	5.50	5.88	5.78	5.76
Nov.	5.13	5.43	5.72	5.87	5.38	5.01	5.75	5.49	5.47
Dec.	2.71	4.40	4.32	4.58	4.49	4.53	4.48	3.84	4.17
Av	5.91	5.26	5.17	5.36	4.89	5.02	5.54	4.75	5.23

Estimated error at 90% confidence level, ±0.15 mR/wk.

Table 3

1963 BNL Environmental Monitoring
Monthly Average Ar^{41} Radiation Levels, mR/wk

	On site			Perimeter				Off site
Month	E-10	E-11	E-12	E-2	E-4	E-7	E-9	O-6
Jan.	1.46	2.08	2.59	0.45	0.26	0.28	0.76	0
Feb.	0.06	2.22	2.92	0.06	0.11	0.76	0.76	0.03
Mar.	0.68	2.58	2.25	0.58	0.05	0.57	0.57	0.03
Apr.	0.78	1.94	2.59	0.14	0.19	1.08	0.74	0.01
May	0.44	6.55	5.19	0.43	0.24	0.41	1.86	0.01
June	0.85	2.31	2.43	0.82	0.32	0.57	0.74	0.02
July	0.35	2.56	4.30	0.47	0.25	0.42	1.49	0.03
Aug.	0.64	3.18	5.02	0.17	0.01	0.48	1.02	0
Sept.	1.63	3.07	3.83	0.21	0.70	0.27	0.55	0.03
Oct.	1.51	2.68	3.46	0.41	0.57	0.53	0.80	0.02
Nov.	0.90	2.16	3.40	0.31	0.39	0.45	0.58	0.04
Dec.	0.58	1.60	1.17	0.19	0.25	0.39	0.35	0.04
Av	0.82	2.74	3.26	0.35	0.28	0.52	0.85	0.02
Peak weekly av	3.23	12.91	7.57	1.97	1.94	1.63	2.29	1.08

Estimated error at 90% confidence level, ±0.25 mR/wk.

comparisons in this and immediately following summaries, the stations have been grouped according to location on site, at the perimeter, and off site.

Since the yearly average maximum permissible nonoccupational exposure of 10 mR/wk to individuals living in the vicinity of the Laboratory is in addition to natural background, determinations of the latter are routinely made. "Natural" background levels, as measured by 6-liter, atmospheric-pressure ion chambers which reflect some deposition of fallout radioactivity, are reported in Table 2, and a monthly composite average of all stations is shown in Figure 2. The natural background levels observed during 1963 were higher than any previously observed since the environmental monitoring program was established at Brookhaven National Laboratory. The next highest, observed in 1959, averaged just under 4.00 mR/wk for the year. The preoperational natural background during 1949-50 was 1.7 mR/wk.

The ion chambers used in making these background level measurements were positioned 6 in. above the monitoring station's roof. A limited number of comparison measurements, made during the fall of 1963, indicated that a typical background outdoors at 3 ft above the ground was $\approx$65% of the roof value. The background inside one of the BNL monitoring stations was found to be $\approx$40% of that on its roof. Background in a typical 2-story home was 1.9 mR/wk at that time.

The "natural background" at a given station is assumed to be the radiation level prevailing during the portion of the week when meteorological records and an inspection of the 4-hr integrated radiation level indicate that the reactor effluent, with its Ar^{41} content, has not been in the vicinity of the station. BGRR shutdowns, as well as the operation of the ecology forest source, are also taken into consideration.

The only measurable increase above natural background attributable to Laboratory operations at most of the monitoring stations is caused by the activated Ar^{41} component of the BGRR cooling air. Kanne chamber measurements indicated an average Ar^{41} stack concentration of 1.75×10^{-3} μCi/cc and a discharge of 19,150 Ci/day of 110-min half-life Ar^{41} when the BGRR was in operation at close to 20 MW. Although the MRR stack concentration of Ar^{41} is 3×10^{-4} μCi/cc and the discharge is 75 Ci/day at full power (3 MW), during 1963 the MRR was infrequently operated at this power level. During 1963 $\approx$5 Ci/wk were discharged from the MRR stack so that the MRR was insignificant as a source of Ar^{41} when compared to the BGRR. Radiation levels at each of the monitoring stations attributable to Ar^{41} are shown in Table 3 and in Figures 3, 4, and 5.

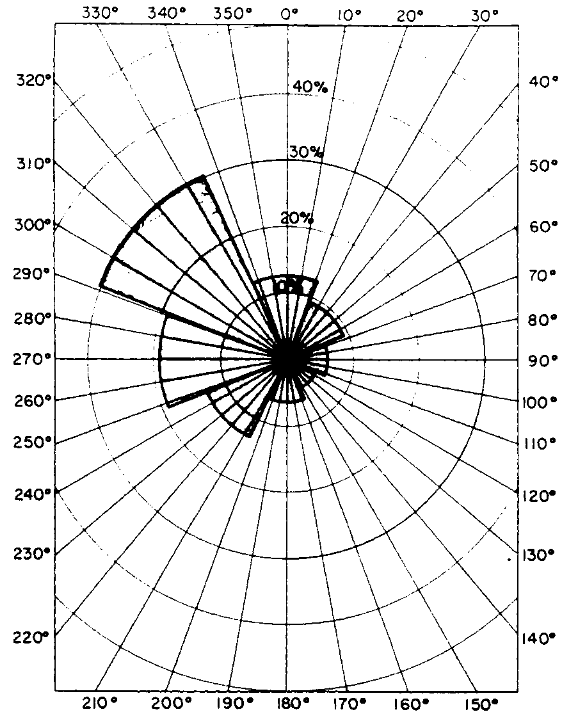

Figure 6. Percentage frequency of 355-ft wind direction, 1953-1959, Jan., Feb., March.

Wind roses for different meteorological "seasons" and the year are shown in Figures 6 through 10. The seasonal patterns apparent from these wind roses can be correlated reasonably well with the monthly variations in the Ar^{41} reported at the various monitoring stations.

Two multicurie field gamma sources are routinely exposed 20 hr/day. One, a 3500-Ci (as of January 1963) Co^{60} source, is used primarily for plant irradiations in a cultivated plot, and the other, an 8800-Ci (as of January 1963) Cs^{137} source, is used to irradiate an otherwise undisturbed wooded area for ecological studies. This area, $\approx$800 meters equidistant from the north and east boundaries (see Figure 1), is close enough so that the dose-rate at the boundary is measurable. Monthly average radiation levels at station E-9 (on the northeast perimeter) attributable to the Cs^{137} source are

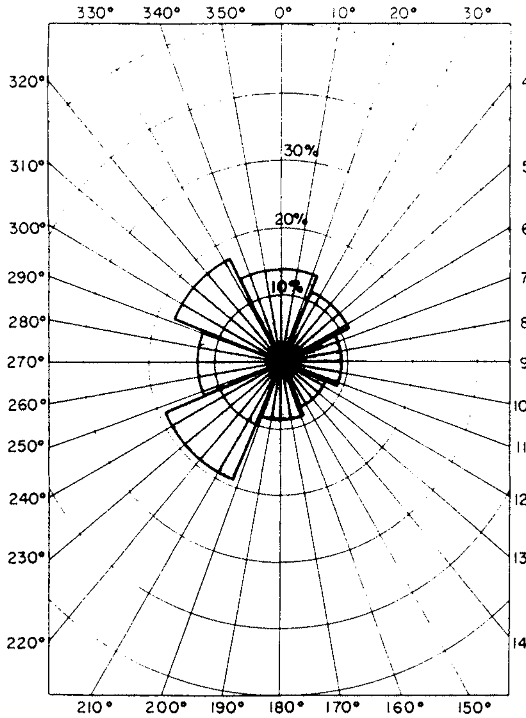

Figure 7. Percentage frequency of 355-ft wind direction, 1953-1959, April, Oct.

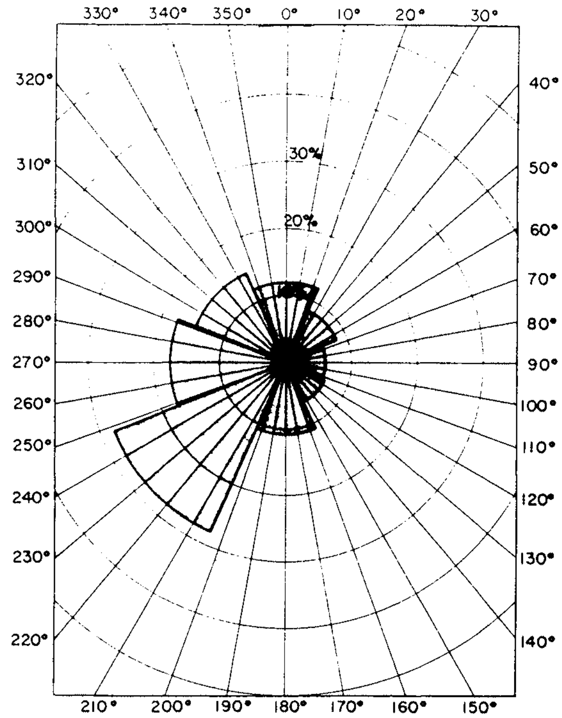

Figure 8. Percentage frequency of 355-ft wind direction, 1953-1959, May-June, July, Aug., Sept.

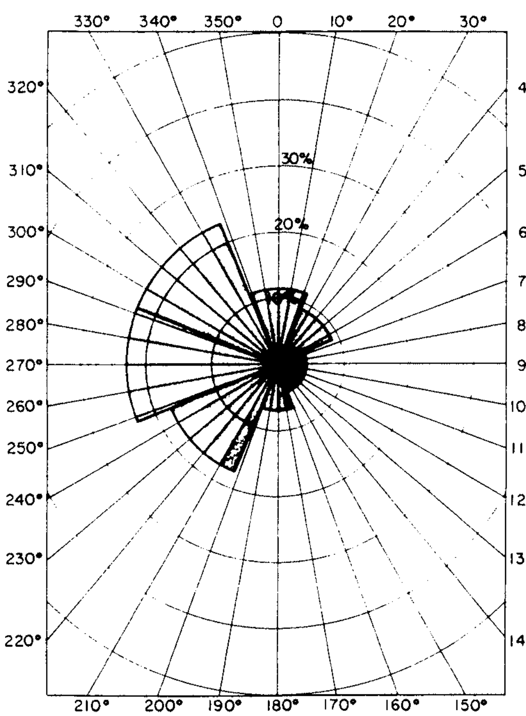

Figure 9. Percentage frequency of 355-ft wind direction, 1953-59, Nov., Dec.

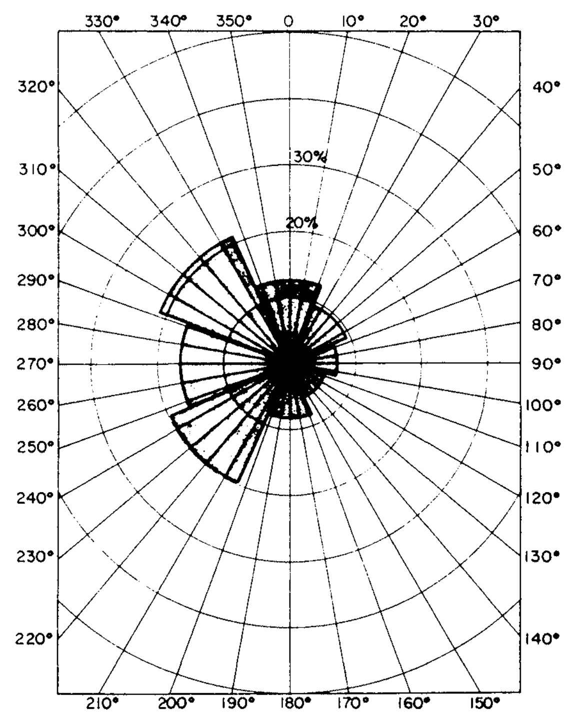

Figure 10. Percentage frequency of 355-ft wind direction, 1953-1959, annual.

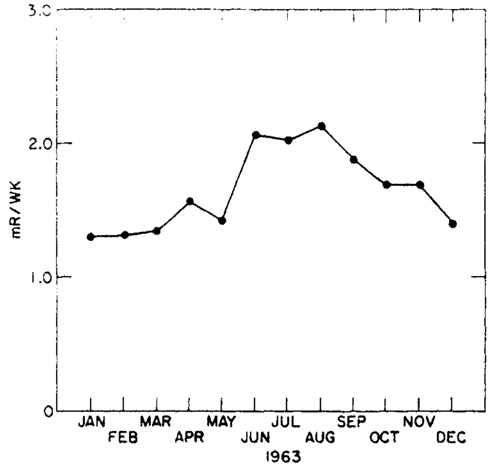

Figure 11. Monthly average radiation level at station E-9 from ecology forest source.

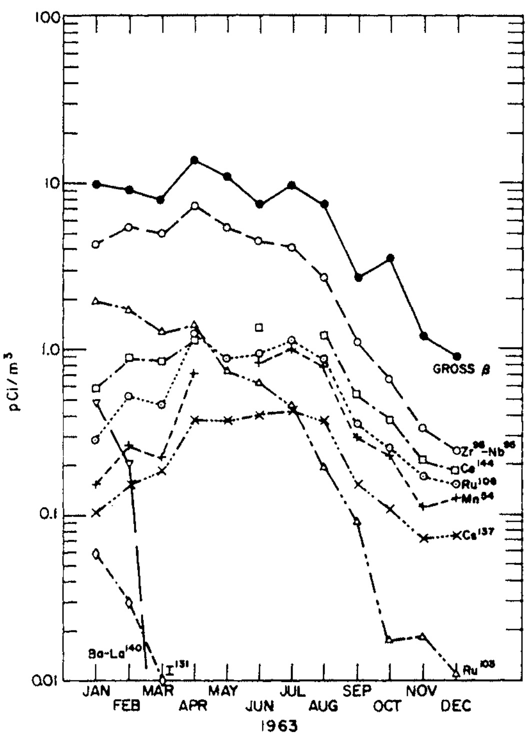

Figure 12. Monthly average air particulate concentrations.

Table 4

1963 BNL Environmental Monitoring
Monthly Average Ecology Forest Source
Radiation Levels (Station E-9), mR/wk

Month	Mean T, °F	mR/wk Observed	mR/wk Calculated	Obs./Calc.
Jan.	28.0	1.30	2.20	0.59
Feb.	25.9	1.31	2.26	0.58
Mar.	39.3	1.39	2.37	0.59
Apr.	47.1	1.56	2.69	0.58
May	55.2	1.42	3.00	0.47
June	66.4	2.06	3.31	0.62
July	69.9	2.02	3.51	0.58
Aug.	67.3	2.13	3.44	0.62
Sept.	59.3	1.88	3.18	0.59
Oct.	55.8	1.68	2.92	0.56
Nov.	46.4	1.69	2.50	0.68
Dec.	26.7	1.35	2.23	0.60
Av	48.9	1.65	2.80	0.59

Estimated error at 90% confidence level, ±0.15 mR/wk.

Table 5

1963 BNL Environmental Monitoring
Monthly Average Air Particulate Activity, pCi/m³

Month	On site E-4	On site E-10	Perimeter E-9	Off site O-6	Off site O-6*
Jan.	9.9	8.0	10.5	10.0	6.6
Feb.	9.0	10.9	9.2	8.8	6.5
Mar.	7.8	10.1	8.9	8.7	6.5
Apr.	13.7	14.7	15.1	13.5	10.2
May	11.0	13.4	12.3	11.3	7.9
June	7.5	14.3	11.9	—	7.5
July	9.6	11.7	11.3	10.8	5.9
Aug.	7.3	9.8	10.0	10.3	4.8
Sept.	2.7	7.2	7.0	5.4	2.9
Oct.	3.5	8.8	9.6	7.8	2.5
Nov.	1.2	5.2	3.6	5.0	1.5
Dec.	0.9	3.4	2.0	3.7	0.8
Av	7.1	10.0	9.3	8.7	5.3

Estimated error at 90% confidence level, ±1.5 pCi/m³.
*Measurements taken 30 hr post collection; all others taken 4 hr post collection.

given in Table 4 and are plotted in Figure 11. With use of a method suggested by Cowan and Meinhold[3] and the observed monthly mean temperatures, a monthly dose-rate has been calculated. Attenuation by the shield plug and by the surrounding woods is suggested as the explanation for the discrepancies between observed and calculated levels.

Some radiation from the Co^{60} source also reaches on-site station E-12, but it is an order of magnitude smaller and cannot be measured accurately in the usual presence of the much higher Ar^{41} levels observed at this location. A calculated correction for the source effect was applied to the E-12 "natural background" measurements.

Table 6

1963 BNL Environmental Monitoring, Monthly Average Concentrations of Gamma-Emitting Isotopes, Air Particulate Filters, Station E-4, pCi/m^3

Month	Mn^{54}	Zr^{95}-Nb^{95}	Ru^{103}	Ru^{106}	Cs^{137}	Ba^{140}-La^{140}	Ce^{144}	I^{131}	Gross β
Jan.	0.15	4.43	1.94	0.29	0.10	0.49	0.58	0.06*	9.9
Feb.	0.26	5.40	1.76	0.52	0.15	0.20	0.87	0.03*	9.0
Mar.	0.22	4.98	1.28	0.45	0.18	<0.01	0.82	0.01*	7.8
Apr.	0.70	7.28	1.38	1.18	0.36	—	1.10	<0.005	13.7
May	N.A.	5.42	0.73	0.87	0.36	—	N.A.	<0.005	11.0
June	0.82	4.51	0.63	0.93	0.40	—	1.36	<0.005	7.5
July	1.00	4.23	0.45	1.11	0.43	—	N.A.	<0.005	9.6
Aug.	0.79	2.72	0.19	0.86	0.36	—	1.22	<0.005	7.3
Sept.	0.29	1.09	0.09	0.35	0.15	—	0.52	<0.005	2.7
Oct.	0.23	0.66	0.17	0.25	0.11	—	0.37	<0.005	3.5
Nov.	0.11	0.33	0.19	0.17	0.07	—	0.21	<0.005	1.2
Dec.	0.12	0.24	0.11	0.16	0.08	—	0.19	<0.005	0.9
Av	0.43	3.44	0.74	0.60	0.23		0.72	<0.005	7.1
Estimated error	±0.05	±0.25	±0.10	±0.10	±0.05	±0.10	±0.25	±0.005	±1.5

N.A. = not available.

*Based on an estimated 40% collection on a charcoal filter.

AIR PARTICULATE MONITORING

Continuous moving-tape air particulate monitors were operated at 5 ft^3/min at the following environmental monitoring stations: E-10 (on site), E-9 (perimeter), and O-6 (off site). A fixed-filter, 20-ft^3/min sampler was operated during 1963 at the E-4 (perimeter) station. The moving-tape monitors, described in detail in reference 2, include an end-window GM tube detector. Apparent monthly average gross beta air concentrations as determined 4 hr post collection by the moving-tape units are indicated in Table 5. These should be regarded as upper limits, since they are uncorrected for occasional increases in background due to Ar^{41} in the BGRR stack plume.

A laboratory count was made with an end-window GM tube at $\approx$30 hr post collection on a section from the high-volume particulate filter at station E-4. The purpose of this delay was to minimize the contribution from the naturally occurring Pb^{212} (10.6-hr half-life) thoron daughter. This has permitted a more precise determination of the air particulate activity attributable to fallout. A second 30-hr post collection count was also obtained from the moving tape at station O-6. These 30-hr delay concentrations are also shown in Table 5.

The concentrations of all identifiable (concentration $>10^{-2}$ pCi/m^3) isotopes collected by the fixed-filter, high-volume sampler at station E-4 have been determined by gamma spectroscopy. These are indicated in Table 6 and are shown in Figure 12. The average gross beta concentration at station E-4 is also shown. Gaps occur in the Ce^{144} and the Mn^{54} curves where consecutive monthly data were not available. The concentrations of the longer lived isotopes have been determined by 1-year delay counts of the early and mid-1963 monthly composite collections. Initial calculations of the more prominent short-lived isotopes have been adjusted for the presence of longer lived isotopes in an overlapping photopeak region of the gamma spectrum.

Evidence for a "spring maximum" appears in the change with time of the concentrations of the longer lived isotopes, especially that of Cs^{137} for which physical decay is not a significant removal process. Although air concentrations were not calculated at Brookhaven prior to the USSR 1961 test series, if the same correlation existed between air concentrations and "natural backgrounds" prior to 1961 as has since been observed, then the concentrations measured during 1963 represent all-time yearly average highs.

Table 7

1963 BNL Environmental Monitoring
Weekly Rain and Settled Dust Collection and
Average Monthly Gross β Concentration

Week ending	Rainfall, in.	Collection, mCi/mi²		Concentration, pCi/liter
1/6/63		4		none
1/13		120		3620
1/20		140		2710
1/27		148		2270
Total	3.16	412	Av	2791
2/3		209		10900
2/10		26		none
2/17		49		721
2/24		85		751
3/3		126		3380
Total	3.95	495	Av	5663
3/10		107		1330
3/17		242		3360
3/24		105		3240
3/31		10		1530
Total	4.27	464	Av	2825
4/7		17		none
4/14		101		12500
4/21		305		11500
4/28		127		8070
Total	2.22	550	Av	10536
5/5		433		4460
5/12		124		8050
5/19		192		2570
5/26		85		9330
6/2		62		786
Total	3.05	896	Av	4760
6/9		59		1220
6/16		277		1440
6/23		11		none
6/30		57		1850
Total	3.37	404	Av	1427
7/7		78		14000
7/14		147		6220
7/21		136		1660
7/28		3		none
Total	2.10	364	Av	6132
8/4		132		1340
8/11		81		9200
8/18		72		6910
8/25		22		332
9/2		5		none
Total	2.24	312	Av	4573
9/8		9		510
9/15		19		261
9/22		55		991
9/29		68		924
Total	3.75	151	Av	840

Table 7 (continued)

1963 BNL Environmental Monitoring
Weekly Rain and Settled Dust Collection and
Average Monthly Gross β Concentration

Week ending	Rainfall, in.	Collection, mCi/mi²		Concentration, pCi/liter
10/6		6		none
10/13		3		"
10/20		4		"
10/27		4		"
Total	0.22	17	Av	
11/3		60		843
11/10		43		none
11/17		10		489
11/25		8		151
12/1		12		167
Total	5.95	133	Av	441
12/8		38		517
12/15		13		596
12/22		6		640
12/29		17		407
Total	2.39	74	Av	516
Yearly total	36.67	4272		
Monthly av		356		3166

Estimated sampling error, ±10%.

Charcoal cartridges for I^{131} sampling were operated behind the moving-tape particulate filters at all the monitoring stations during the first quarter of 1963 and in high-volume samplers at stations E-4 and E-9 throughout the year. Fallout-associated I^{131} (evident about equally at all stations) declined to below the lower limit of detection by March. Monitoring devices operated by Health Physics Division personnel indicated that I^{131} totaling 2.4 Ci was emitted at an almost uniform rate from the BGRR stack during 1963 in an average concentration of 7×10^{-10} μCi/cc. Meteorological considerations indicate that the average air concentrations of I^{131} at the perimeter stations were $\leqslant 2 \times 10^{-15}$ $\mu Ci/cm^3$, which is below the limit of detection for the analytical methods used during 1963.

RAIN AND SETTLED DUST COLLECTION

A daily collection was made from a pot-type rain collector (surface area, 0.33 m³) situated adjacent to the BNL Meteorology Building in a pre-

Table 8

1963 BNL Environmental Monitoring, Rain and Settled Dust Collection
Monthly Average Gamma-Emitting Isotopes, Sr^{89}, Sr^{90}, and Gross β Activity, mCi/mi^2

Month	Zr^{95}-Nb^{95}	Ru^{103}	Ru^{106}	Ce^{144}	Cs^{137}	Ba^{140}-La^{140}	I^{131}	Sr^{89}	Sr^{90}	Gross β	Precipitation, in.
Jan.	71.3	62.7	N.A.	20.4	N.A.	1.8	0.7	70.8	7.3	412	2.46
Feb.	74.7	66.9	N.A.	84.0	N.A.	1.2	<0.5	33.6	5.2	497	3.43
Mar.	172	81.0	N.A.	N.A.	N.A.	<1.0	"	N.A.	N.A.	464	3.89
Apr.	156	43.9	14.9	36.4	N.A.	"	"	N.A.	N.A.	551	0.85
May	317	60.5	12.9	84.0	N.A.	"	"	57.1	7.8	897	3.10
June	113	21.5	5.7	110.7	N.A.	"	"	N.A.	2.4	405	4.49
July	77.6	15.8	12.3	28.7	9.7	"	"	18.6	4.8	363	2.22
Aug.	40.4	5.9	8.6	31.4	8.1	"	"	4.3	5.6	311	2.88
Sept.	27.2	5.1	7.6	20.2	1.5	"	"	6.5	12.9	151	2.36
Oct.	<1.0	<1.0	<1.0	4.8	<1.0	"	"	0.1	0.1	5	1.12
Nov.	37.1	6.1	13.5	28.5	14.7	"	"	3.3	3.1	129	5.95
Dec.	3.4	2.3	5.6	16.8	1.5	"	"	1.7	1.6	74	2.39
Total	1120	372	—	—	—	—	—	—	—	4259	35.14
Av	93	27	9*	42*	6*	—	—	22*	5*	355	2.93
Estimated error	±10%	±25%	±25%	±25%	±50%	±25%	±25%	±25%		±10%	

N.A. = not available. *Average for months for which data were available.

vailing upwind direction from the BGRR stack. A standard amount of distilled water was used to wash down the collector if no precipitation was falling at the time the sample was terminated. Weekly totals and average concentrations are indicated in Table 7.

Monthly composite samples were analyzed for identifiable gamma-emitting isotopes, as well as for Sr^{89} and Sr^{90}. The results, along with monthly totals and average concentrations, are shown in Table 8. The monthly amounts of the most prevalent isotopes (Zr^{95}-Nb^{95}, Ce^{144}, and Ru^{103}) and the gross beta activity are also plotted in Figure 13. A prominent "spring maximum" is evident. The collection of April 30, 1963, 397 mCi/mi^2, was the third highest on record at this location since 1953 when rain and settled dust collections were initiated. It was exceeded only by the 436-mCi/mi^2 collection on October 23, 1958, and the 445-mCi/mi^2 collection on September 22, 1954.

LIQUID WASTE MONITORING

Low-level radioactive liquid wastes are routinely disposed of by discharge into the Labora-

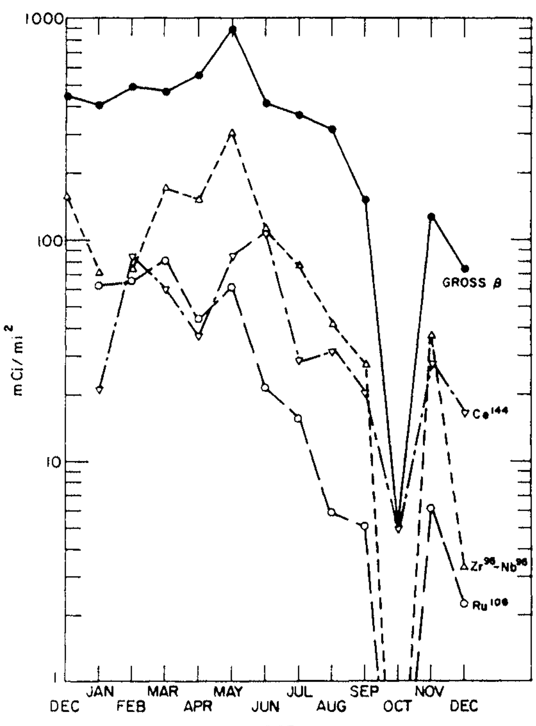

Figure 13. Total monthly collection of rain and settled dust, showing Zr^{95}-Nb^{95}, Ru^{103}, Ce^{144}, and gross beta concentrations.

tory's sanitary waste system, where they are diluted by a large volume of uncontaminated water. The liquid waste effluent passes through an Imhoff tank where most of the solids are removed and then passes through sand filter beds from which it is collected by an underlying tile field. The liquid effluent is then chlorinated and discharged to a small stream that forms one of the headwaters of the Peconic River.

The monitoring arrangements for the central sewage system are indicated in Figure 14. Values of the monthly average concentration and total activity found in the Imhoff tank at the input to the filter bed, at the point of discharge to the river, and at the site boundary (computed on the basis of stream flow) are indicated in Table 9.

A gamma spectrometer scan and a Sr^{90} analysis are performed on a monthly composite of the filter-bed input samples and on a composite of the effluent samples. The concentrations of the three isotopes usually detected, Cs^{137}, Co^{60}, and Sr^{90}, are indicated in Table 10. Ce^{144}, Zr^{95}-Nb^{95}, and Ru^{106} were also found, but generally in amounts too small for satisfactory quantitative determination.

STREAM SAMPLING

Monthly "grab" samples were routinely obtained at locations along the upper tributary of the Peconic River, into which the Laboratory routinely discharges low-level liquid wastes. Reference grab samples were also obtained from other nearby streams and bodies of water outside the Laboratory's drainage area. During 1963 this sampling was extended to include three points between the sewage bed outfall and the east perimeter of the Laboratory site; in this way a better profile was obtained of the decrease in concentration with distance downstream. The sampling locations (see Figure 15) are as follows.

A. Peconic River at Schultz Road, 13,250 ft downstream from BNL boundary.
B. Peconic River at Wading River–Manorville Road, 21,450 ft downstream from BNL boundary.
C. Peconic River at Manorville, ≈35,000 ft downstream from BNL boundary.
D. Peconic River at Calverton, ≈45,000 ft downstream from BNL boundary.
E. Peconic River upstream from BNL effluent outfall.
F. Peconic River at north tributary independent of BNL drainage.

Table 9

1963 BNL Environmental Monitoring
Monthly Average Liquid Effluent Gross β Concentration and Total Activity

	Imhoff tank			Chlorine house			Site boundary		
Month	Flow, gal/day	Conc., pCi/liter	Activity, mCi	Flow, gal/day	Conc., pCi/liter	Activity, mCi	Flow, gal/day	Conc.,* pCi/liter	Activity,* mCi
Jan.	622,000	176	12.9	525,000	163	10.0	633,000	135	10.0
Feb.	624,000	119	8.7	550,000	97	6.3	638,000	84	6.3
Mar.	613,000	170	11.1	528,000	122	6.9	945,000	68	6.9
Apr.	626,000	126	9.3	506,000	164	9.7	819,000	101	9.7
May	734,000	117	9.8	572,000	106	6.9	508,000	84	4.8
June	851,000	115	11.5	659,000	114	8.9	425,000	82	4.1
July	1,016,000	106	12.2	778,000	119	10.6	796,000	103	9.3
Aug.	1,208,000	96	13.6	968,000	71	8.1	830,000	71	7.0
Sept.	1,015,000	128	15.3	859,000	116	11.7	802,000	116	10.9
Oct.	975,000	81	9.0	773,000	86	7.5	710,000	86	6.9
Nov.	687,000	76	6.1	601,000	101	7.1	640,000	95	7.1
Dec.	574,000	123	8.0	447,000	113	5.7	633,000	80	5.7
Total	—	—	127.5	—	—	99.4	—	—	88.7
Av	796,594	116	—	648,197	111	—	696,621	92	—
Estimated error		±15	±1.0		±15	±1.0		±15	±1.0

*Calculated from flow measurements.

G. Carmans River, Middle Island.
H. Carmans River, at outflow of Yaphank Lake.
I. Artist Lake (maintained by water table, no surface outflow).
J. Lake Panamoka (maintained by water table, no surface outflow).
K. Peconic River, just below BNL effluent outfall.
L. Peconic River, 1000 ft below BNL effluent outfall.
M. Peconic River, at BNL boundary.

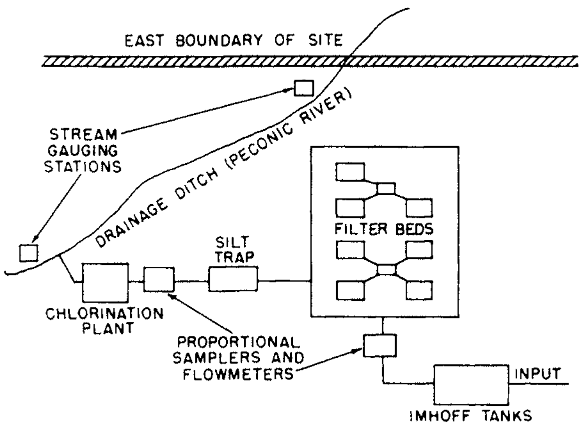

Figure 14. BNL sewage processing and monitoring system.

Table 10

1963 BNL Environmental Monitoring Liquid Effluent Concentrations of Cs^{137}, Co^{60}, and Sr^{90}, pCi/liter

	Imhoff tank			Chlorine house		
Month	Cs^{137}	Co^{60}	Sr^{90}	Cs^{137}	Co^{60}	Sr^{90}
Jan.	24	<5	16	74	20	10
Feb.	14	<5	12	62	<5	9
Mar.	54	9	19	83	22	14
Apr.	24	65	9	77	79	11
May	16	46	5	50	38	18
June	45	24	8	45	<5	14
July	10	32	3	70	29	6
Aug.	11	<5	6	40	<5	6
Sept.	7	<5	5	31	<5	5
Oct.	17	<5	3	30	<5	5
Nov.	6	27	4	36	23	7
Dec.	9	44	2	26	68	4
Weighted av	18	20	7	51	20	9
Estimated error	±5	±5	±2	±5	±5	±2

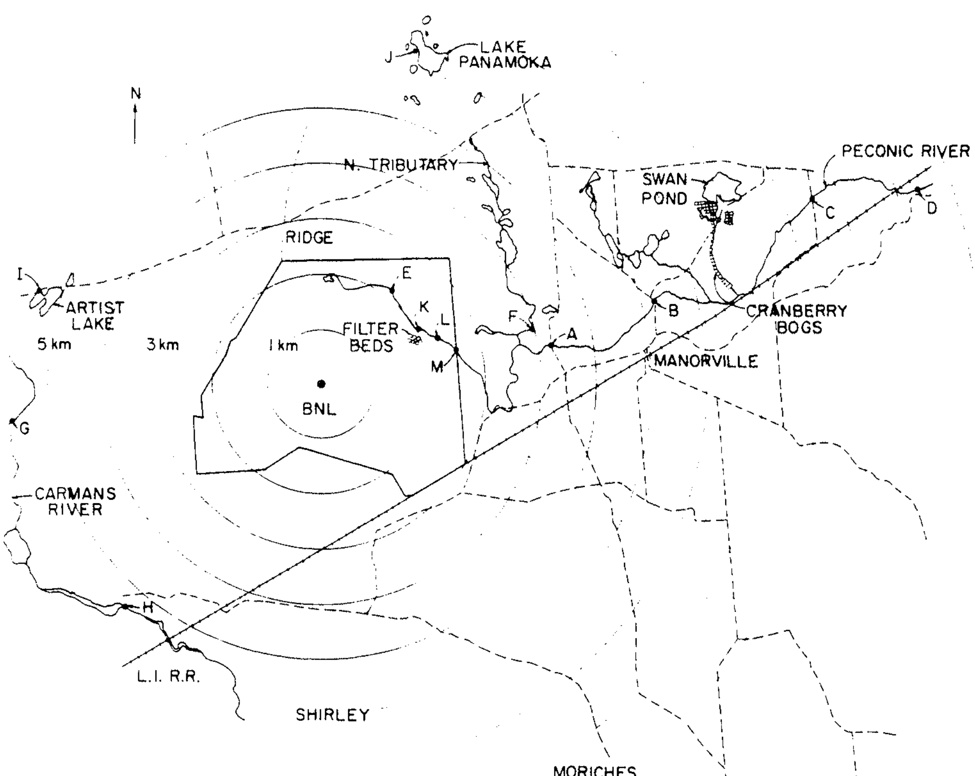

Figure 15. Environmental monitoring stream sampling points.

Table 11

1963 BNL Environmental Monitoring
Monthly Stream Sample Gross β Concentrations, pCi/liter

	Peconic River (proceeding downstream)								Controls				
Month	E	K	L	M	A	B	C	D	F	G	H	I	J
Jan.	50	—	—	—	55	48	53	26	50	9	3	30	31
Feb.	32	—	—	—	34	37	31	47	32	<3	11	30	17
Mar.	82	—	—	—	24	44	29	19	82	7	52	23	60
Apr.	47	117	90	—	92	69	105	187	47	29	88	52	47
May	35	34	91	24	103	134	189	66	35	6	52	145	64
June	50	86	93	—	52	63	135	37	50	10	34	54	63
July	35	126	39	—	44	31	46	18	35	<5	12	120	43
Aug.	27	85	72	47	39	16	41	14	27	9	16	38	32
Sept.	14	34	—	31	32	22	22	20	14	23	7	35	12
Oct.	21	35	—	12	23	14	19	7	21	24	6	19	20
Nov.	29	40	43	61	38	18	23	19	29	7	6	23	9
Dec.	18	105	106	59	13	11	10	21	18	33	8	27	18
Av	37	61	74	—	46	42	59	40	37	13	25	50	35

Estimated error at 90% confidence level: for a value <10 pCi/liter, ±5; 10 to 25, ±10; 25 to 100, ±15; >100, ±25.

Table 12

1963 BNL Environmental Monitoring
Concentration in Stream Bottom Sediment and Vegetation
(values for K in g/kg; all others in pCi/g)

			Gamma-emitting isotopes				
Location	Month	Type	Ce^{144}	Cs^{137}	Zr^{95}-Nb^{95}	Co^{60}	K
Peconic River							
E	Apr.	Sed.	<0.2	0.5	<0.2	<0.5	1.6
L*	May	Sed.	"	3.4	"	"	2.2
L*	Nov.	Sed.	"	0.4	"	"	2.6
M	Apr.	Sed.	"	12.0	"	1.6	**
A	Apr.	Sed.	"	2.1	"	1.6	**
A	Nov.	Sed.	"	0.9	"	<0.5	1.3
B	Apr.	Sed.	"	1.0	"	"	**
B	Nov.	Sed.	0.7	0.5	0.1	"	1.5
C	Apr.	Sed.	<0.2	0.6	1.5	"	—
C	June	Veg.	5.9	1.5	14.6	"	—
C	Nov.	Sed.	2.4	0.9	1.7	"	1.7
C	Nov.	Veg.	4.0	1.4	3.0	"	2.5
D	Apr.	Sed.	<0.2	0.2	1.6	"	—
D	Nov.	Sed.	0.4	0.1	0.4	"	1.8
D	Nov.	Veg.	6.3	0.7	7.9	"	3.3
Controls							
F	Apr.	Sed.	<0.2	0.5	<0.2	<0.5	**
F	Nov.	Sed.	0.4	0.3	"	"	2.4
F	Nov.	Veg.	11.7	7.9	7.0	"	4.4
G	Apr.	Sed.	<0.2	0.3	0.8	"	1.8
H	Apr.	Sed.	"	0.1	0.7	"	2.4
H	Nov.	Sed.	1.4	0.2	0.6	"	4.6
I	Apr.	Sed.	<0.2	0.3	0.6	"	2.2
I	Nov.	Sed.	2.0	0.9	1.3	"	2.5
J	Apr.	Sed.	0.6	0.1	2.2	"	1.4
Estimated error			±0.2	±0.2	±0.2	±0.5	±0.1

*This location was dredged to improve the flow within the Laboratory site in August 1962.
**No analysis made.

Table 13

1963 BNL Environmental Monitoring
Concentration in Cranberries,* pCi/g

Location	Gamma-emitting isotopes			
	Ce^{144}	Cs^{137}	Zr^{95}-Nb^{95}	Sr^{90}
Manorville				
Upper bog	0.3**	1.2**	<0.2	0.05
Lower bog	0.1	0.7	<0.2	N.A.
Wild berries	0.4	3.2	0.1	N.A.
Calverton				
Wild berries	0.2	0.2	0.2	N.A.
Nonlocal				
Cape Cod (?)	0.2	0.3	0.2	0.07
Estimated error	±0.2	±0.2	±0.2	±0.05

*All berries were harvested in October, 1963.
**Average of two samples.
N.A. = not available.

Stream concentrations found during 1963 are summarized in Table 11. To facilitate comparisons, the samples are divided into two groups, one of Peconic River samples, in sequence from upstream to downstream, and the other a control group.

A few sediment and underwater vegetation samples were also obtained during 1963. Gamma scans were performed, and the more prominent emitters identified are indicated in Table 12.

Since there is an abundant underground supply of water on Long Island, the Peconic River is not used as a drinking water supply or for irrigation. Its waters are occasionally used to flood the lower bogs of a commercial cranberry operation ≈8 miles downstream from the Laboratory. In the fall of 1963, samples of mature berries from both the upper and lower bogs of this farm, of wild berries from a nearby pond, of wild berries from a location 9 miles downstream, and of berries of other than local origin were obtained. As indicated in Table 13, no effect attributable to the use of Peconic River water to flood the lower bog was ascertainable.

WELL SAMPLING

The Laboratory's potable water wells and cooling water supply wells are ≈100 ft deep, or 50 ft below the water table in the Long Island surface layer of glacial till. They are generally west to northwest and upstream from most of the facilities of the Laboratory. The exceptions are principal potable water wells Nos. 1 and 3, the smaller well No. 5 at the sewage plant, and the one at the waste and reclamation area (Figure 16). Monthly gross beta results are summarized in Table 14.

MILK SAMPLING

Meteorological predictions of average ground concentrations of I^{131} emitters from the BGRR, and reasonable assumptions about I^{131} deposition and the relationship between grass and milk concentrations, lead to the conclusion that the amounts of I^{131} in the milk from cows pastured in the vicinity of the Laboratory are generally <1 pCi/liter, well below the lower limit of detection.

The results of a routine monthly sampling program are given in Table 15. Some locations were sampled more frequently than once a month, in which case the number of samples is shown in parentheses and the values are averages.

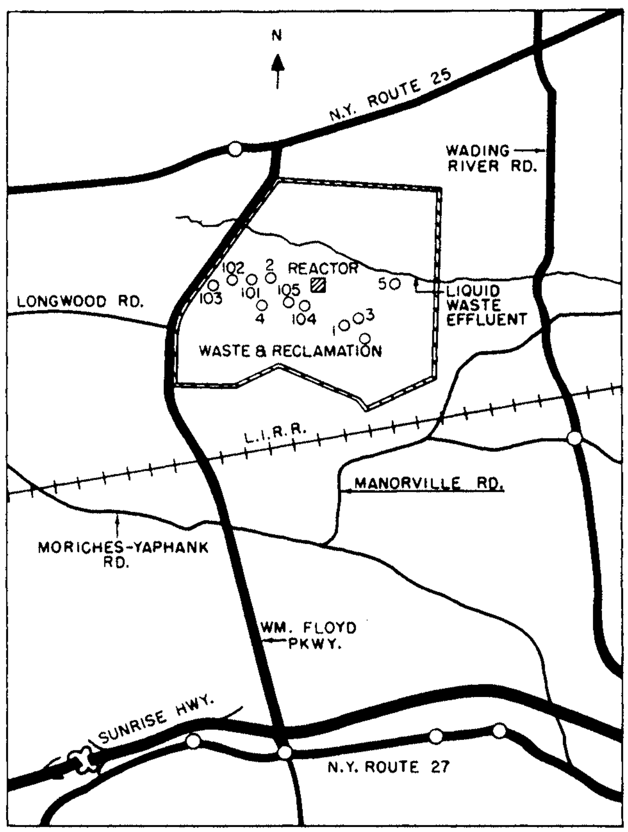

Figure 16. Location of BNL water supply wells.

Table 14

1963 BNL Environmental Monitoring
Deep Well Samples, Gross β Concentrations, pCi/liter

Month	Potable water well No.						Cooling supply well No.				
	1	2	3	4	5	W&R*	101	102	103	104	105
Jan.	5.3	—	7.9	7.4	1.4	6.9	4.1	6.7	—	—	—
Feb.	7.0	—	<2.5	8.3	<2.5	<2.5	25.3	12.4	<2.5	—	—
Mar.	<1.3	—	3.2	5.3	1.3	8.7	4.0	2.2	3.9	—	—
Apr.	2.7	—	6.2	2.0	1.9	1.8	4.7	1.3	2.6	—	—
May	2.1	<1.0	4.8	<1.0	8.3	<1.0	6.2	4.4	7.1	5.7	4.0
June	1.6	3.3	<1.2	3.8	2.8	—	—	1.7	4.6	1.8	<1.2
July	5.5	3.5	2.1	<2.0	11.1	2.9	—	7.1	—	12.4	<2.0
Aug.	2.5	2.4	<2.0	<2.0	2.0	6.1	<2.0	1.5	2.2	<2.0	4.4
Sept.	4.7	3.9	2.1	3.0	3.0	3.2	7.1	1.8	3.5	2.4	<1.2
Oct.	2.5	6.0	2.0	3.1	2.3	5.5	1.4	6.7	6.1	1.7	1.2
Nov.	1.1	3.6	1.3	1.8	3.4	1.6	1.1	3.8	3.6	2.7	4.7
Dec.	3.2	3.8	3.2	1.5	2.7	—	2.2	1.6	2.2	2.1	—
Av**	3.1	3.4	3.0	3.2	3.5	3.8	5.7	4.3	3.7	3.7	2.4

Estimated error as indicated, or ± 1 pCi/liter, at 90% confidence level.
*Waste disposal and reclamation well.
**In averaging, samples measuring less than background were considered to be half of background.

VEGETATION SAMPLING

During the pasture season, monthly samples of grass were obtained from all the farms participating in the milk-sampling program. An additional grass-sampling location was established at a potato farm 6 km northeast of the BGRR stack in order to fill in the sampling grid nearby, since primary interest was in the possibility of detecting I^{131} deposition. Because there is an interfering photopeak in the 0.36-MeV region from the naturally occurring Pb^{214} daughter of radon, the nearby samples were compared with the outlying control samples. Since the control samples averaged an "equivalent" of 0.04 μCi/g of I^{131} higher than the nearby samples, and since the nearby sample from the most prevailing downwind direction (northeast) averaged the lowest in "equivalent" I^{131}, it was concluded that the average I^{131} deposition nearby was <0.05 μCi/g.

The monthly average concentrations of other identifiable gamma-emitting isotopes are presented in Table 16. The amount of potassium present was determined from the K^{40} photopeak. From this information and from a knowledge of the average air concentrations of Ru^{103} and of Zr^{95}-Nb^{95} during the months immediately preceding the start of the pasture season, a deposition velocity of 0.1 ± 0.05 cm/sec was calculated for both of these fission product isotopes.

SUMMARY

Measurements have been made of "natural background" radiation levels (including fallout contributions) during 1963 in the environment of Brookhaven National Laboratory and vicinity. Perturbations in this natural background attributable to Laboratory operations, i.e., radiation from the Ar^{41} content of the BGRR cooling-air effluent, from an ecology field gamma source, and from the discharge of low-level liquid wastes, have also been measured.

The natural background, as measured 6 in. above roof level, reached 6.22 mR/wk in August. This is attributable to fallout from the large-scale weapons testing conducted during the fall of 1962 and is the highest level on record at this location. The corresponding background at an elevation of 3 ft was $\approx$65% of that at 6 in.

The highest yearly average on-site environmental radiation level attributable to Laboratory

Table 15

1963 BNL Environmental Monitoring
Concentrations of Cs^{137} and I^{131} and Amount of K in Milk Samples
(values for K in g/liter; all others in pCi/liter)

	Farm *A** (3 km NW)			Farm *B* (6 km SW)			Farm *C* (10 km SE)			Farm *D* (15 km NW)			Farm *E* (30 km NE)		
Month	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K
Jan.	—	—	—	67	<10	1.4 (2)	92	<10	1.3	—	—	—	39	<10	1.4
Feb.	—	—	—	50	<10	1.5	—	—	—	—	—	—	—	—	—
Mar.	162	<10	1.9	93	<10	1.5	—	—	—	—	—	—	—	—	—
Apr.	157	<10	1.4	58	<10	1.5	110	<10	1.4	—	—	—	65	<10	1.5
May	224	<10	1.8 (2)	96	<10	1.7 (2)	85	<10	1.5 (2)	—	—	—	114	<10	1.6 (2)
June	180	<10	1.5	107	<10	1.3	101	<10	1.5	—	—	—	185	<10	1.4
July	—	—	—	135	<10	1.2 (2)	138	<10	1.2 (2)	141	< 3	1.3	—	—	— (3)
Aug.	189	<10	1.9	138	<10	1.6 (2)	138	<10	1.5 (2)	188	<10	1.5	—	—	— (2)
Sept.	143	5	1.4	120	3	1.2	125	<3	1.2 (2)	135	3	1.4	—	—	— (2)
Oct.	122	5	1.7	164	<3	1.6	157	<3	1.3 (2)	151	<3	1.4	—	—	— (2)
Nov.	—	—	—	164	<3	1.6	151	<3	1.6	144	<3	1.4	—	—	—
Dec.	—	—	—	141	<10	1.4	155	<3	1.1	148	<3	1.5	—	—	—
Av	175	<10	1.7	111	<10	1.5	126	<10	1.4	136	<10	1.4**			

Estimated error at 90% confidence level: Cs^{137}, ±15; I^{131}, Jan.-Aug., ±10, and Sept.-Dec., ±3; K, ±0.2.
*One animal, with unlimited pasture; all other samples are composites from the production of a herd.
**Farms *D* and *E* were averaged together as controls.

Table 16

1963 BNL Environmental Monitoring
Monthly Average Concentrations of Gamma-Emitting Isotopes in Vegetation, pCi/g

Month	Ce^{144}	Ru^{103}*	Ru^{106}*	Zr^{95}-Nb^{95}	Cs^{137}	K
July	2.6	1.5	0.6	7.9	<2.0	5.1
Aug.	14.4	3.3	4.1	24.5	"	10.0
Sept.	10.7	1.4	2.7	15.4	"	6.6
Oct.	10.3	0.9	1.9	10.9	"	7.4
Nov.	12.3	1.3	2.2	10.7	2.2	5.9
Period av	10.1	1.7	2.3	13.9	—	7.0
Estimated error	±1.0	±0.5	±0.5	±1.0	±0.5	±0.5

*The ratios between Ru^{103} and Ru^{106} were assumed to be those of fission products of an "age" determined for the air samples taken during the same month.

operations was 3.3 mR/wk (for 168 hr), well below the established maximum permissible exposure (MPE) level of 100 mR/wk (for 40 hr).[4] The highest yearly average radiation level at the perimeter was 2.50 mR/wk, to which the ecology forest contributed 1.65 mR/wk and the balance was from Ar^{41}. The total is 25% of the established MPE of 10 mR/wk (for a 168-hr week) for nonoccupational exposure.[4]

No activity attributable to Laboratory operations was detectable in air particulate monitoring samples. The yearly average gross beta concentration of two samples counted after a 30-hr delay, to allow for the decay of almost all the natural radioactivity, was 6.7 pCi/m³. This may be compared to an established maximum permissible concentration (MPC) of 100 pCi/m³.[5] The principal constituent of the air particulate collection, Zr^{95}-Nb^{95}, averaged 3.4 pCi/m³, or 51% of the total. Fallout I^{131} concentrations in air declined below the limit of detection (0.005 pCi/m³) during the first quarter of 1963. No measurable concentration attributable to Laboratory operations was detectable at this limit.

The activity in a rain and settled dust collection averaged 356 mCi/mi² (141 nCi/m²) per month. The average concentration in measurable precipitation was 3166 pCi/liter.

Liquid wastes discharged to the headwaters of the Peconic River averaged 92 pCi/liter, $\approx$20% of a calculated permissible off-site drinking water concentration which is based on the observed 10% Sr^{90} content. Monthly downstream grab sample averages ranged from 42 to 74 pCi/liter, while those from off-site control locations ranged from 13 to 50 pCi/liter. Some evidence of increased concentrations of Cs^{137} and of the presence of Co^{60} attributable to BNL released activity was found in stream bottom sediment and vegetation collections as far as 7 miles downstream. On-site potable water supply wells averaged 3.6 pCi/liter.

The concentrations of I^{131} in milk samples obtained from several nearby farms were all <10 and generally <5 pCi/liter. This is within Range I of the applicable Radiation Protection Guide (RPG) levels. assuming an intake of 1 liter/day. The highest yearly average RPG level is the upper limit of Range II, 100 pCi/day intake. The deposition of I^{131} was found to be <0.05 μCi/g.

During 1963, radiation levels attributable to Laboratory operations were maintained well below the established MPE, MPC, and RPG levels for whole-body exposures, air particulate concentrations, and liquid effluent concentrations. Radiation levels attributable to fallout were also below these established limits.

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