BNL 50001 (T-427)
(Health and Safety — TID-4500)

1964 ENVIRONMENTAL MONITORING RADIATION LEVELS AT BROOKHAVEN NATIONAL LABORATORY

A. P. HULL

June 1966

BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

Printed in the United States of America
Available from
Clearinghouse for Federal Scientific and Technical Information
National Bureau of Standards, U.S. Department of Commerce
Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.65

March 1967 875 copies

ABSTRACT

Measurements of "natural background" radiation levels (including fallout contributions) and of perturbations in this background attributable to Laboratory operations have been obtained on site and in the vicinity of Brookhaven National Laboratory. These perturbations include contributions from the gaseous and air particulate effluent of the stack of the Brookhaven Graphite Research Reactor, from multicurie field gamma sources, and from the discharge of low-level liquid wastes into the headwaters of the Peconic River.

The natural background external radiation level declined to an average of 2.93 mR/wk during 1964. No increment was perceptible from fallout from the first Chinese weapons test, which was detected here late in October. The highest yearly on-site level attributable to Laboratory operations was 3.22 mR/wk (for 168 hr), well below the established radiation protection standards for individuals in controlled areas. The highest yearly radiation level at the perimeter averaged 2.57 mR/wk, to which the ecology forest contributed 1.59 mR/wk; the balance was from Ar^{41}. The total is 26% of the established yearly standard of 500 mR for individuals in uncontrolled areas.

No airborne radioactivity attributable to Laboratory operations, other than I^{131}, was detectable during routine environmental monitoring. The yearly average gross β concentration of samples counted after a 30-hr delay (to allow for the decay of almost all the natural radioactivity) was 1.10 pCi/m^3, with a 1-day maximum of 9.27 pCi/m^3 on October 28.

The possibility of using the low level of I^{131} as a meteorological tracer to study stack effluent dispersion prompted a more intensive effort to sample and evaluate very low environmental concentrations of airborne I^{131} during 1964. The highest yearly average at the perimeter was determined to be 0.0037 pCi/m^3, which may be compared with the radiation protection standard concentration of 100 pCi/m^3 in uncontrolled areas. Fallout I^{131} from the first Chinese nuclear weapons test was also present in an average concentration of 0.0062 pCi/m^3 from October 28 to November 29.

The activity in precipitation declined to an average of 78 mCi/mi^2/mo. The average concentration was 339 pCi/liter.

Liquid wastes discharged to the headwaters of the Peconic River averaged 72 pCi/liter, about 6.7% of a calculated radiation protection standard that assumes the Sr^{90} content to be 20% and the balance of the isotopes present to be "unknown" β or γ emitters. Monthly downstream "grab" samples from the Peconic River ranged from 115 to 14 pCi/liter, while those from off-site control locations averaged 17 pCi/liter. The highest concentrations of individual isotopes in bottom sediments (11.2 pCi/g of Co^{60}, 6.9 pCi/g of Cs^{137}, and 1.3 pCi/g of Ce^{144}) were found between the on-site outfall and a point about a mile downstream from the Laboratory perimeter. A similar distribution was found in underwater vegetation, the highest concentrations being 34.3 pCi/g of Co^{60}, 13.3 pCi/g of Ce^{144}, and 4.0 pCi/g of Cs^{137}. Concentrations in both sediment and vegetation were found to decline to near background levels beyond three miles downstream.

The concentrations of I^{131} in routine monthly milk samples obtained from several nearby farms were all <10 pCi/liter, except for a brief time early in November. The applicable Radiation Protection Guide, assuming an intake of 1 liter/day, is 100 pCi/liter.

The environmental monitoring program has established that during 1964 radiation levels attributable to Laboratory operations were maintained well below the established radiation protection standards of the AEC for external exposures, air particulate concentrations, and liquid effluent concentrations. Radiation levels attributable to fallout were also well below these established limits.

1964 ENVIRONMENTAL MONITORING RADIATION LEVELS AT BROOKHAVEN NATIONAL LABORATORY

INTRODUCTION

Environmental monitoring data have been obtained in the vicinity of Brookhaven National Laboratory since 1949. Annual reports of the information were instituted in 1962. Up to the present, these reports[1,2] have been published primarily to document the record levels of fallout that occurred following the resumption of atmospheric testing of nuclear devices in 1961. The decreasing levels of fallout in the environment have facilitated some current investigations of low-level additions to environmental radioactivity originating from the Laboratory. The 1964 report makes available both the fallout data and the results of the investigations of local effects.

The evaluation of radiation levels in the vicinity of the Laboratory site is performed by the Environmental Monitoring Section of the Health Physics Division. Laboratory operations contribute three principal additions to the local natural background radiation: (1) gaseous and particulate radioactivity contained in the cooling-air effluent of the Brookhaven Graphite Research Reactor (BGRR) and the Medical Research Reactor (MRR), and in the off-gas of the Hot Laboratory (discharged from the BGRR stack); (2) radiation from two multicurie field γ sources; and (3) 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 1964 are summarized in this report. Although much reduced from the record 1963 levels, fallout from the atmospheric testing of nuclear weapons during 1961 and 1962 was observed in 1964 in many types of environmental samples. Some fresh fission products were also evident for a brief period after the Chinese weapons test in mid-October. While the identification of fallout is only an incidental aspect of the Environmental Monitoring Section's activities, such information about fallout radioactivity levels as has been obtained is summarized.

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

EXTERNAL EXPOSURE MONITORING

Environmental radiation levels, including natural background (as influenced by fallout) and the increments attributable to the reactor cooling-air effluent and the ecology forest sources, were monitored continuously at seven fixed monitoring stations. As indicated in Figure 1, two of these stations are on site, four are at the perimeter, and one is off site. (A third on-site station, E-10, adjacent to the former Health Physics administration building about 500 meters southwest of the BGRR stack, was discontinued during 1964.) The equipment of each station includes an ion chamber and dynamic capacitor electrometer assembly (described in detail in ref. 3), which is capable of accurately measuring $<10\,\mu$R/hr and of detecting changes of the order of 1 μR/hr. Although information about the instantaneous dose rate up to about 0.5 mR/hr may be obtained from these units, normally the integrated radiation over 4-hr periods was used to obtain weekly averages, and these in turn were used to com-

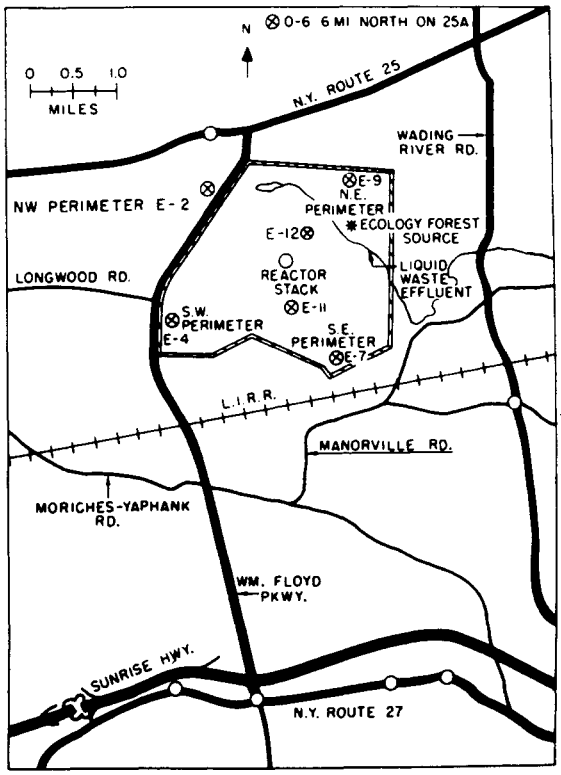

Figure 1. BNL environmental monitoring stations.

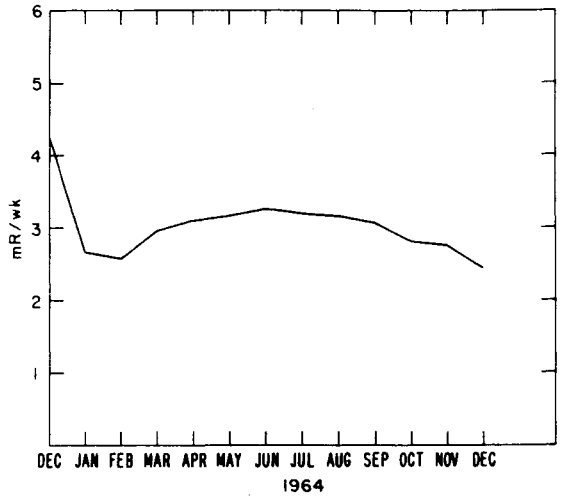

Figure 2. Monthly average background radiation levels, 1964.

pute the monthly data presented in Tables 1 to 4.

Monthly average gross external radiation levels are set forth in Table 1. For convenience in making 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 established radiation protection standard[4] of 500 mR/yr for 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 "all-station" average background level is shown in Figure 2. These ion chambers are now positioned 2 ft above the roof of each monitoring station. Measurements made at this height are in close agreement with those made at 3 ft above the ground surface in the vicinity of the stations. Prior to 1964 the ion chambers were positioned 6 in. above roof level. At this elevation, background measurements were about 1-1/2 times comparison measurements made at the 2-ft elevation. Yearly natural background levels (including fallout) from the initiation of observations at this site in 1949 to the present are indicated in Figure 3. The maxima for 1959 and 1963 are the result of large series of weapons tests in 1958 and 1961-62. The data were adjusted to correspond to the present elevation of the ion chambers.

Natural background at a given station is assumed to be the radiation level prevailing during the portion of the week when meteorological data and an inspection of the 4-hr integrated radiation indicated that the reactor plume had not been in the vicinity of the station. Reactor shutdowns, as well as the operation of the ecology forest source, were 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

Table 1

1964 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-6
Jan.	3.06	3.85	3.94	2.65	2.82	3.06	5.10	2.47
Feb.	3.30	4.45	4.00	2.52	2.74	3.72	4.11	2.38
Mar.	3.99	4.87	5.81	2.97	3.32	3.78	5.80	2.69
Apr.	4.12	5.51	6.62	3.45	3.39	3.84	5.73	2.86
May	6.33	5.08	7.10	3.26	4.04	3.66	6.22	2.94
June	4.99	6.65	8.75	3.38	3.62	3.99	6.68	2.99
July	*	4.95	9.21	3.19	3.35	3.93	7.80	2.86
Aug.		4.81	8.66	3.11	3.38	3.75	6.93	2.86
Sept.		6.07	6.78	2.91	3.48	3.38	5.90	2.72
Oct.		5.58	6.11	2.60	2.76	3.75	5.29	2.64
Nov.		4.86	4.36	2.88	2.78	3.45	4.93	2.50
Dec.		6.33	4.95	2.21	2.40	3.15	4.37	2.26
Av		5.25	6.36	2.93	3.17	3.62	5.74	2.68

*Station discontinued July 9, 1964.

Table 2

1964 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.	2.69	2.60	2.39	2.50	2.69	2.63	3.65	2.37	2.69
Feb.	2.79	2.99	2.33	2.41	2.66	2.80	2.59	2.27	2.58
Mar.	2.98	3.09	3.08	2.77	2.81	3.13	3.25	2.63	2.96
Apr.	3.13	3.16	3.12	2.91	3.00	3.40	3.37	2.72	3.10
May	3.51	3.44	3.10	3.01	3.05	3.42	3.39	2.85	3.18
June	3.52	3.49	3.18	3.11	3.20	3.47	3.32	2.88	3.24
July	*	3.34	3.04	3.11	3.03	3.52	3.45	2.83	3.19
Aug.		3.25	3.16	2.92	3.00	3.38	3.42	2.83	3.14
Sept.		3.39	3.10	2.83	2.87	3.27	3.20	2.70	3.05
Oct.		3.05	2.84	2.51	2.60	3.05	2.91	2.63	2.80
Nov.		2.85	2.78	2.58	2.58	3.09	2.91	2.48	2.75
Dec.		2.60	2.44	2.16	2.30	2.74	2.56	2.24	2.43
Av		3.10	2.88	2.74	2.82	3.16	3.17	2.62	2.93

*Station discontinued July 9, 1964.

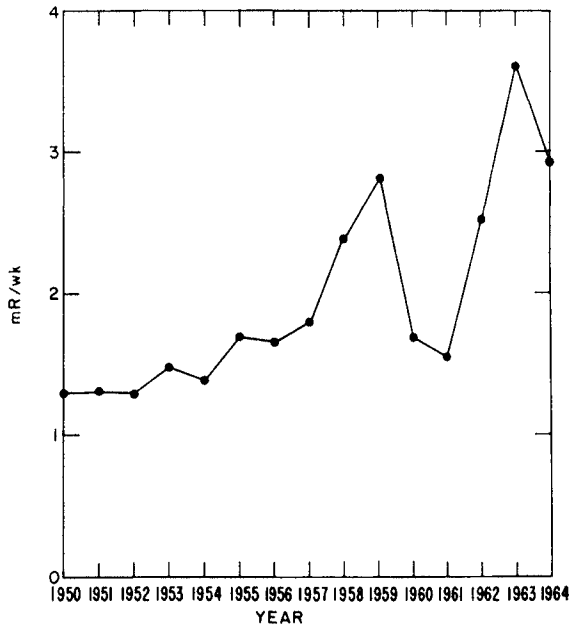

Figure 3. Yearly background at 3-ft elevation, 1949-1964.

effluent. Kanne chamber measurements indicated an average Ar^{41} stack concentration of 1.8×10^{-3} pCi/cm^3 during 1964 and a discharge of 20,600 Ci/day of 110-min half-life Ar^{41} while the BGRR was in operation at close to 20 MW. Although the MRR stack concentration of Ar^{41} is 3×10^{-4} pCi/cm^3 and the discharge is 75 Ci per 24-hr day at full power (3 MW), the MRR was infrequently operated at this power level during 1964. About 5 Ci/wk were discharged from its stack, so that it was insignificant as a source of Ar^{41} when compared with the BGRR. The yearly average radiation levels at each of the monitoring stations which were attributable to Ar^{41} are shown in Table 3. Assuming the plume to be of several mean free paths (for the Ar^{41} 1.29-MeV γ rays) in dimension, a dilution factor of 500,000 can be calculated from the observed Ar^{41} radiation level at station E-9.

The percentage frequencies of wind directions to the nearest 10° during the years 1961 to 1963 have recently been

Table 3

1964 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.	0.37	1.25	1.34	0.15	0.13	0.43	0.21	0.10
Feb.	0.51	1.46	1.46	0.11	0.08	0.92	0.39	0.11
Mar.	1.01	1.78	2.51	0.20	0.51	0.65	1.11	0.06
Apr.	0.99	2.35	3.25	0.54	0.39	0.44	1.04	0.14
May	2.82	1.64	3.71	0.25	0.99	0.24	1.25	0.09
June	1.47	2.16	5.27	0.27	0.42	0.52	1.31	0.11
July	*	1.61	5.87	0.08	0.32	0.41	2.27	0.03
Aug.		1.56	5.21	0.19	0.38	0.37	1.51	0.03
Sept.		2.68	3.38	0.08	0.61	0.11	0.88	0.02
Oct.		2.53	3.00	0.09	0.16	0.70	0.80	0.01
Nov.		1.24	1.35	0.30	0.20	0.36	0.41	0.02
Dec.		1.82	2.31	0.05	0.10	0.41	0.56	0.02
Av		1.92	3.22	0.19	0.36	0.46	0.98	0.06

*Station discontinued July 9, 1964.

tabulated by the BNL Meteorology Group. The results, by meteorological seasons, and the annual average are shown in Figures 4 to 8. The seasonal patterns apparent from these wind roses can be correlated reasonably well with the monthly variations in the Ar^{41} reported at the individual monitoring stations.

Two multicurie field γ sources are routinely exposed 20 hr/day. One, a 3050-Ci (as of January 1964) Co^{60} source, is used primarily for plant irradiations in a cultivated plot, and the other, an 8500-Ci (as of January 1964) Cs^{137} source, is used to irradiate an otherwise undisturbed wooded area for ecological studies. The latter, about 800 meters equidistant from the north and east boundaries (see Figure 1), is close enough so that its 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 given in Table 4. With use of a method suggested by Cowan and Meinhold[5] and the observed monthly mean temperatures, a monthly dose rate has

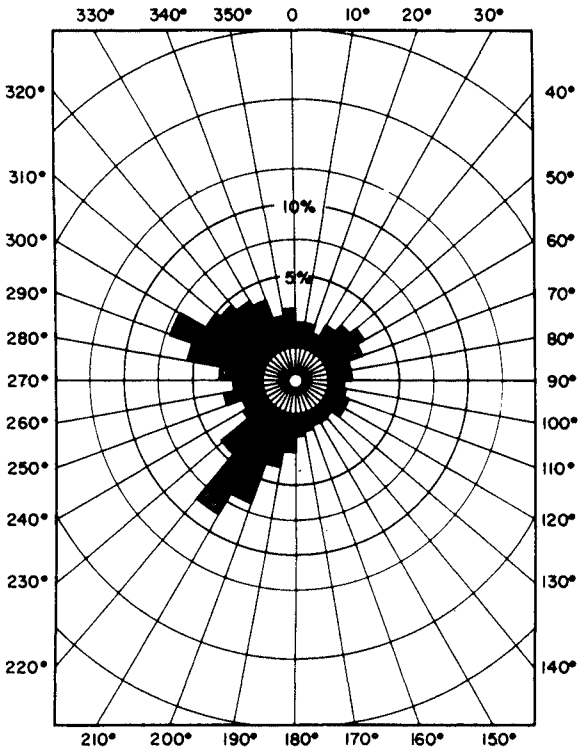

Figure 5. Percentage frequency of 355-ft wind directions, 1961-1963, Apr., Oct.

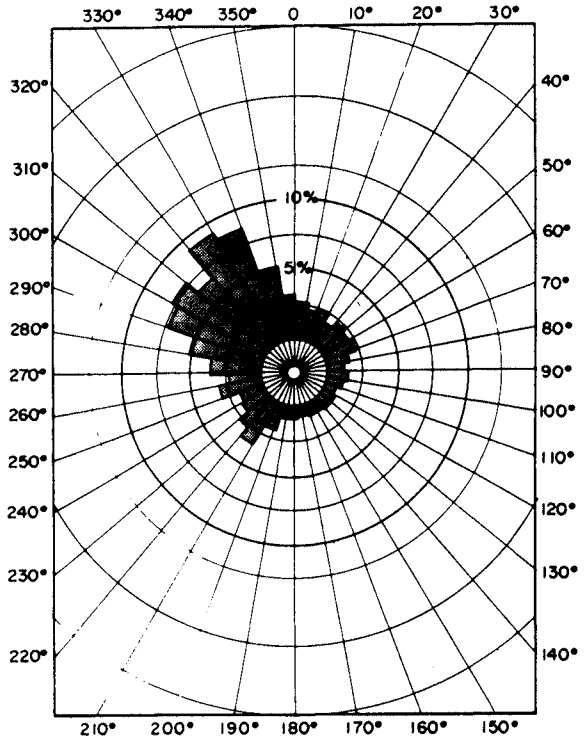

Figure 4. Percentage frequency of 355-ft wind directions, 1961-1963, Jan., Feb., Mar.

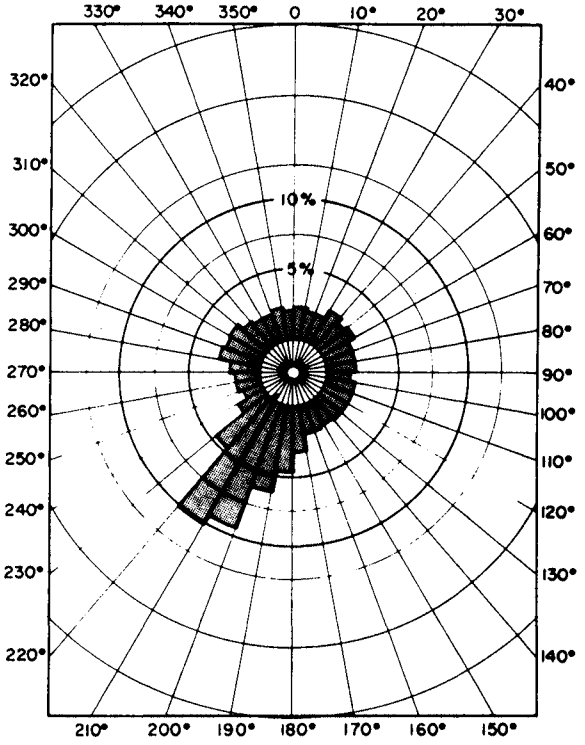

Figure 6. Percentage frequency of 355-ft wind directions, 1961-1963, May-Sept.

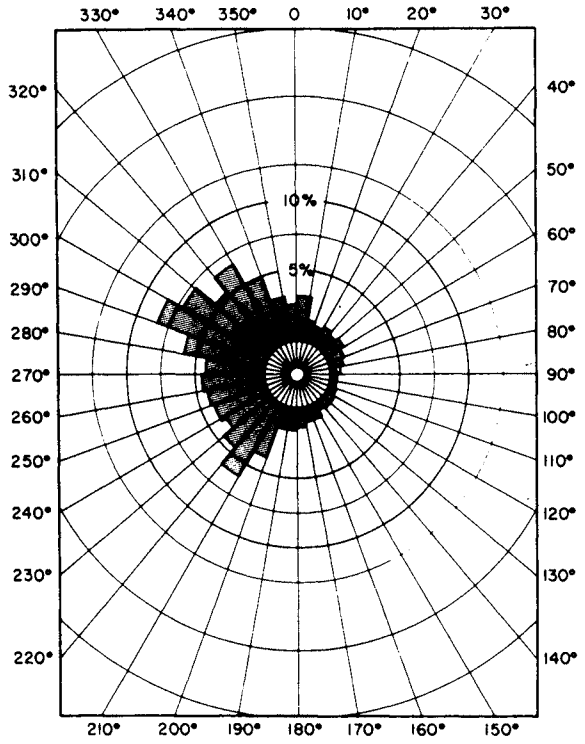

Figure 7. Percentage frequency of 355-ft wind directions, 1961-1963, Nov., Dec.

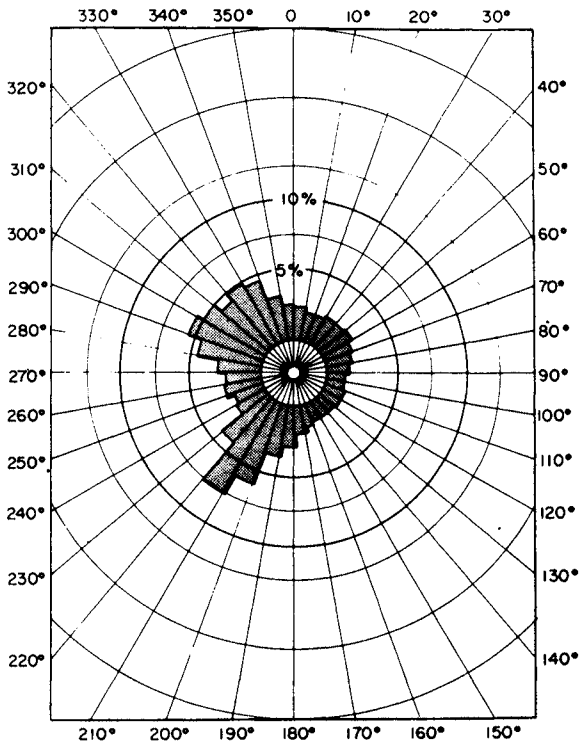

Figure 8. Percentage frequency of 355-ft wind directions, 1961-1963, annual.

Table 4

1964 BNL Environmental Monitoring
Monthly Average Radiation Levels, Ecology Forest Source (Station E-9)

Month	Mean T, °C	mR/wk		
		Observed	Calculated	Obs./Calc.
Jan.	-1.0	1.24	2.24	0.55
Feb.	-1.7	1.13	2.20	0.51
Mar.	3.0	1.44	2.44	0.59
Apr.	6.6	1.32	2.56	0.52
May	15.1	1.58	3.19	0.50
June	18.2	2.05	3.38	0.61
July	21.8	2.08	3.49	0.60
Aug.	18.8	2.00	3.40	0.59
Sept.	16.4	1.82	3.26	0.55
Oct.	10.4	1.58	2.84	0.56
Nov.	6.0	1.61	2.56	0.63
Dec.	1.7	1.25	2.38	0.53
Av		1.59	2.83	0.56

been calculated. Attenuation by the shield plug and by the surrounding woods is suggested as the explanation for the lower values for the observed radiation 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.

AIR PARTICULATE MONITORING

At the beginning of 1964, "high-volume" (20 ft^3/min) air samplers were installed in monitoring stations E-2, E-7, and E-9. Thus, with the unit already in operation at E-4, there is a high-volume sampler at 90° intervals on the perimeter of the Laboratory site. These units replaced the 5-ft^3/min moving-tape samplers previously employed at these locations. Particulate filters (MSA No. C-17651) 4 in. in diameter were usually operated for a 2-wk sampling interval.

Gross β counts were made with an end-window GM tube at about 30 hr postcollection on a section from the particulate filters. This delay served to minimize the contribution from the naturally occurring Pb^{212} (10.6-hr half-life) thoron daughter. A γ analysis of the entire filter sample was then made.

A moving-tape air particulate sample counted after a 20-min delay indicated that during 1964 the average gross β concentration of the stack effluent was 1.4×10^{-7} μCi/cm^3. Although routine analyses for specific radionuclides other than I^{131} were not made, the stack sample obtained on Nov. 11-13 was analyzed in detail. The concentrations of detectable isotopes with half-lives > 1 day are given in Table 5. No activity uniquely attributable to these stack effluent isotopes was detectable on the routine 2-wk air particulate samples at downwind environmental monitoring stations. No significant differences in gross β or individual isotope concentrations were apparent between the samples obtained at stations in the prevailing downwind direction and those seldom downwind. The calculated ground level concentrations of the particulate stack effluent isotopes are too small for detection in the presence of the prevailing background of natural and fallout activity.

Monthly average "30-hr delay" gross β concentrations and the average concentrations of all identifiable (concentration > 10^{-3} pCi/m^3) γ-emitting isotopes are indicated in Table 6 and are shown in Figure 9. Initial calculations of short-lived isotopes have been adjusted for the presence of longer-lived isotopes with overlapping photopeaks in the same spectrum.

A "spring maximum," related to the transfer to the troposphere from the stratospheric reservoir of aged nuclear

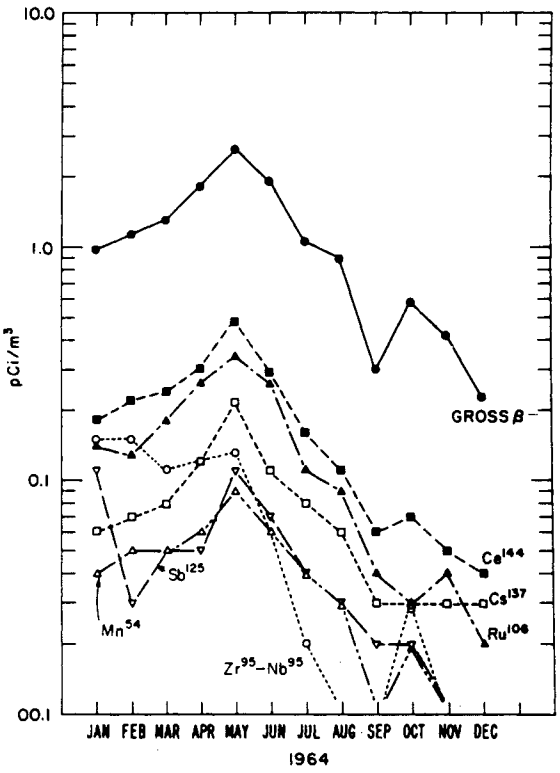

Figure 9. Monthly average air particulate concentrations, 1964.

Table 5

1964 BNL Environmental Monitoring Concentration of Radionuclides With Half-Lives >0.1 h in Air Particulate Filter Sample of Stack Effluent, Nov. 11-13

		$T_{1/2}$	pCi/m^3
Activation isotopes	Na^{24}	15.0 h	472 ± 25%
	Br^{82}	35.7 h	111 ± 25%
	Zn^{65}	245 d	2.4 ± 25%
	Co^{60}	5.26 y	0.7 ± 50%
	Hg^{203}	47 d	1.0 ± 50%
Total			597
Fission product isotopes	Mo^{101}-Tc^{101}	14 m	7,590 ± 25%
	I^{134}	53 m	5,830 ± 25%
	I^{135}	6.7 h	4,020 ± 25%
	Zr^{97}-Nb^{97}	17 h	181 ± 25%
	I^{133}	20.8 h	1,310 ± 25%
	Mo^{99}	66 h	156 ± 25%
	I^{131}	8.05 d	130 ± 25%
	Ba^{140}-La^{140}	12.8 d	108 ± 25%
	Np^{239}	2.10 d	6.8 ± 50%
	Zr^{95}-Nb^{95}	65 d	3.3 ± 50%
	Ru^{103}	40 d	2.0 ± 50%
	Ce^{141}	32.5 d	1.1 ± 50%
	Ce^{144}	285 d	1.0 ± 50%
	Cs^{137}	30 y	0.6 ± 50%
	Ru^{106}	1.0 y	0.4 ± 50%
Total			15,050

debris from the high-yield weapons tests of 1961-62, is apparent. A smaller peak in the gross β concentration was caused by the presence in the troposphere of fresh nuclear debris from the low-yield Chinese nuclear test of October 16, 1964.

Charcoal cannisters (MSA No. C-46727) for I^{131} sampling were operated in sequence after the particulate filters in the continuous high-volume samplers for the same 2-wk sampling periods. After a delay of two or three days immediately following the sampling period (again to allow for the decay of radon and thoron progeny), a complete γ spectrum (from 0.1 to 3.0 MeV) was made for both types of filter. At the stack, about 1% of the emitted radioiodine is filterable on a 2-day particulate sample.[6] Stack-emitted I^{131} has not been detectable on routine field air particulate filters, and it is assumed that all this iodine is collected in the charcoal cannister.

Corrections for decay during collection were made with the assumption, to a first approximation, of a uniform concentration over the sampling interval. Bi^{214} (RaC) interference from the radium inherent in the filter medium was cancelled out by a dual count procedure. Following the initial 5-hr spectrum, the charcoal cannisters were set aside for about a month and then recounted. The net difference in the 0.36-MeV photopeak region was inter-

Table 6

1964 BNL Environmental Monitoring, Monthly Average Gross β and γ-Emitting Isotope Concentrations, Air Particulate Filters, pCi/m^3

Month	Gross β*	Mn^{54}	Zr^{95}-Nb^{95}	Ru^{103}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{141}	Ce^{144}
Jan.	0.98	0.04	0.15	<0.01	0.14	0.10	0.06	<0.01	0.18
Feb.	1.12	0.05	0.15	0.02	0.13	0.03	0.07	< 0.01	0.22
Mar.	1.31	0.05	0.11	<0.01	0.18	0.05	0.08	<0.01	0.24
Apr.	1.82	0.06	0.12	<0.01	0.26	0.05	0.12	<0.01	0.30
May	2.61	0.09	0.13	<0.01	0.34	0.11	0.22	<0.01	0.48
June	1.91	0.06	0.06	<0.01	0.26	0.07	0.11	<0.01	0.29
July	1.05	0.04	0.02	<0.01	0.11	0.04	0.08	<0.01	0.16
Aug.	0.90	0.03	0.01	<0.01	0.09	0.03	0.06	<0.01	0.11
Sept.	0.30	0.01	<0.01	<0.01	0.04	0.02	0.03	<0.01	0.06
Oct.	0.59	0.02	0.03	0.03	0.03	0.02	0.03	0.02	0.07
Nov.	0.42	0.01	<0.01	<0.01	0.04	0.01	0.03	<0.01	0.05
Dec.	0.23	0.01	<0.01	<0.01	0.02	0.01	0.03	<0.01	0.04
Av	1.10	0.04	0.06	<0.01	0.14	0.05	0.08	<0.01	0.18
Estimated error	±0.10	±0.01	±0.01	±0.01	±0.02	±0.01	±0.01	±0.01	±0.03

*Measured 30 hr postcollection.

preted as the amount of I^{131} that had decayed during this interval. From the occasional "negative I^{131}" results (used in calculating averages), the net error of an individual measurement appeared to be ± 5 pCi or ± 0.001 pCi/m^3.

Monitoring devices operated by Health Physics Division personnel indicated that a total of 2.05 Ci of I^{131} were emitted at an almost uniform rate from the BGRR stack during 1964 in an average concentration of 6.5×10^{-10} μCi/cm^3. The BNL Meteorology Group[7] has calculated average concentrations for the perimeter monitoring stations as a function of the seasonal wind direction and stability distributions during 1960-1963. In this calculation typical daytime parameters were assumed, and it was also assumed that no stack I^{131} concentrations would be observed at ground level during inversion conditions. A comparison between the calculated and observed annual concentrations during 1964 at each perimeter station is shown in Table 7.

Fallout I^{131} in the atmospheric debris from a low-yield nuclear device, tested above ground in China on October 16, 1964, reached Long Island at ground level on October 28. As shown in Table 8, the air particulate concentrations were sharply peaked on that date, and decay studies confirmed the origin of this material. Since the time sequence of air activity seemed similar to that which might be observed in the event of a large-scale reactor release or other nuclear incident, a somewhat more than routine amount of attention was given to the analysis of this sample and to determining the related environmental concentrations.

The first γ spectrum of the October 28-29 air particulate sample was run on October 29, and a number of successive

Table 7

1964 BNL Environmental Monitoring
Calculated and Measured Annual Concentrations of
I^{131} at the BNL Perimeter

Station	Distance from stack, km	Downwind direction	pCi/m³	
			Calculated	Measured
E-2 (NW)	1.8	140°	0.0007	$0.0001^{+0.0003}_{-0.0001}$
E-4 (SW)	2.2	65°	0.0008	0.0009±0.0003
E-7 (SE)	2.5	321°	0.0014	0.0014±0.0004
E-9 (NE)	2.75	217°	0.0018	0.0037±0.0009

Table 8

1964 BNL Environmental Monitoring
Gross β Air Particulate Concentration,
Station E-4, Oct. 22-Nov. 4

Date*	pCi/m³
10/22-23	0.20
10/23-24	0.88
10/24-25	0.88
10/25-26	0.88
10/26-27	1.20
10/27-28	0.90
10/28-29	9.27
10/29-30	2.18
10/30-31	1.01
10/31-11/1	0.91
11/1-2	1.01
11/2-3	0.91
11/3-4	0.57

*Samples changed at 0900.

spectra were run over the next few weeks to establish the decay rates of the different peaks. Isotopes were identified solely from considerations of energy and half-life, with no radiochemical separations. Their concentrations were estimated from published decay schemes and the known photopeak efficiency of the BNL detector. The isotopes and concentrations ascertained in this manner are listed in Table 9.

The concentrations of fallout I^{131} and Ba^{140}-La^{140} were followed for several sampling periods through the following month (see Table 10). The Ba^{140}-La^{140} data are in close agreement with those reported for New York City and Westwood, N.J., by the Health and Safety Laboratory.[8]

Table 9

1964 BNL Environmental Monitoring
Fission Product and Np^{239} Concentrations
in Air, Oct. 28-29

Isotope	Concentration, pCi/m³	% of Gross β*
Mo^{99}	0.16	1.7
Ru^{103}	0.55	6.1
I^{131}	0.72**	8.1
Te^{132}	0.65	7.3
Ba^{140}	0.76	8.5
Ce^{141}	0.31	3.5
Nd^{147}	0.20	2.2
Np^{239}	0.32	-
Gross β	9.27	

*Less Np^{239}.
**Calculated from Oct. 15-29 samples.

Table 10

1964 BNL Environmental Monitoring
Average Concentrations of I^{131} and Ba^{140}-La^{140}, Nov.

Sampling period	I^{131}, pCi/m³					Ba^{140}-La^{140}, pCi/m³
	Particulate	(%)	Charcoal	(%)	Total	Particulate
10/28-10/29*	0.522	(72)	0.185	(28)	0.715	1.078
10/30-11/5	0.011	(29)	0.021	(71)	0.032	0.050
11/6-11/12	0.006	(29)	0.015	(71)	0.021	0.037
11/13-11/15	0.004	(37)	0.012	(76)	0.016	0.020
11/16-11/29	0.002	(20)	0.006	(80)	0.008	0.009

*Calculated from Oct. 16-29 sample, by assuming that entire I^{131} and Ba^{140}-La^{140} collection was made on Oct. 28-29.

The data confirm that the observed fallout air concentrations were sharply peaked on October 28-29 (assuming a negligible collection prior to the 28th) and that there were trailing edges of both I^{131} and Ba^{140}-La^{140} which diminished at rates corresponding to their half-lives. They also suggest that the initial collection of I^{131}, during the October 28-29 peak, was quite different in physical form from subsequent collections. Whereas about 70% of the early iodine was collected on the particulate prefilter and 30% on the following charcoal cartridge, these ratios were subsequently reversed, which suggests a problem in deducing the total concentrating of airborne I^{131} from a single type of sample.

About two weeks later, on November 11-12, about 150 mCi of I^{131} was inadvertently released from the Hot Laboratory off-gas system (which discharges to the atmosphere through the BGRR stack). Another 134 mCi was discharged, at a gradually diminishing rate of release, between the 12th and the 16th. The source of the activity was discovered and closed off on the 16th.

A distribution by hours of wind directions during the release period was provided by the Meteorology Group. Assuming no local deposition during inversion conditions, the noninversion winds were separated into two principal directions, southwesterly until 2130 on November 13, and northwesterly thereafter. A brief interval of easterly winds occurred on the morning of the 16th. Since a routine filter change was made on the 13th and a "special" change on the 16th, some resolution of what occurred prior to and following the wind shift was possible.

Table 11 gives the concentrations at the affected (downwind) stations, after subtracting the average residual I^{131} background from the Chinese weapons test detected at the unaffected stations.

Unfortunately, the quantity of I^{131} released was poorly resolved, with regard to time, so that a detailed comparison between calculated and measured air concentrations was not practical. By using the approximation that the release rate declined exponentially with time, it was possible to determine integrated ground concentrations for the observed wind frequency distribution. Curves relating integrated ground-level air concentrations to BGRR stack emission, for various disper-

Table 11

1964 BNL Environmental Monitoring, Average Perimeter Concentrations of I^{131} Attributed to Hot Laboratory Release from BGRR Stack on Nov. 11-16

Station	Distance from stack, km	Downwind direction	Average concentration, pCi/m³ Particulate	(%)	Charcoal	(%)	Total	Period
E-9 (NE)	2.75	217°	.0067	(11)	.0650	(89)	.0717	11/11-13
E-7 (SE)	2.5	34°	.0003	(1)	.0430	(99)	.0433	11/13-16
E-4 (SW)	2.2	65°	.0011	(29)	.0027	(71)	.0038	11/13-16

sion conditions, have been published in connection with the evaluation of a postulated fuel element failure incident.[9] The calculated and the observed integrated concentrations of I^{131} attributed to the November 13-16 release are given in Table 12.

PRECIPITATION COLLECTION

A pot-type rain collector with a surface area of 0.33 m^2 is located adjacent to the BNL Meteorology Building, in a prevailing upwind direction from the BGRR stack. Because of the decreasing amounts of "dry" fallout at the beginning of the year, the collection was changed from a daily to a precipitation basis, i.e., a sample was picked up at 0900 only if precipitation had been observed during the previous 24 hr. 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.

Part of each collection was evaporated for gross β counting. The largest 24-hr rainout, 48.4 mCi/m^2 at a concentration of 4620 pCi/liter, occurred on June 6-7. Weekly composite samples were analyzed for identifiable γ-emitting isotopes, and monthly composite samples for Sr^{89} and Sr^{90}. Monthly average gross β concentrations, monthly amounts of gross β activity, and individual isotopes in precipitation are indicated in Table 13. The monthly amounts of gross β activity and of the more prevalent isotopes, Ce^{144},

Table 12

1964 BNL Environmental Monitoring, Integrated Perimeter Concentrations of I^{131} Attributed to Hot Laboratory Release from BGRR Stack on Nov. 11-16

Station	Downwind Hr	Downwind Date	Dispersion condition	Estimated release while downwind, mCi	Integrated air concentration, Ci-sec/m³ Predicted	Observed
E-9 (NE)	9	11/12	B_2	50	2.0×10^{-8}	1.2×10^{-8}
E-7 (SE)	10	11/13-16	B_1	15	0.8×10^{-8}	1.2×10^{-8}
E-4 (SW)	4	11/16	C	2	0.2×10^{-8}	0.1×10^{-8}

Ru^{106}, Cs^{137} and Zr^{95}-Nb^{95}, are also plotted in Figure 10. A spring peak of fallout activity is evident.

Rain and settled dust collections have been made by the Environmental Monitoring Group at Brookhaven National Laboratory continuously since the latter part of 1953. The data from gross β counts of these collections for the years prior to 1962, which have not previously been published, are tabulated by months in Table 14. The contribution from fallout of nuclear weapons debris is suggested by the large collections during or shortly after months for which detonations were reported in a summary by Eisenbud.[10] The spring maximum of fallout is also evident. Total activity for the years 1953 to 1964 is indicated in Figure 11. The amount for 1953 is estimated from the September-December average.

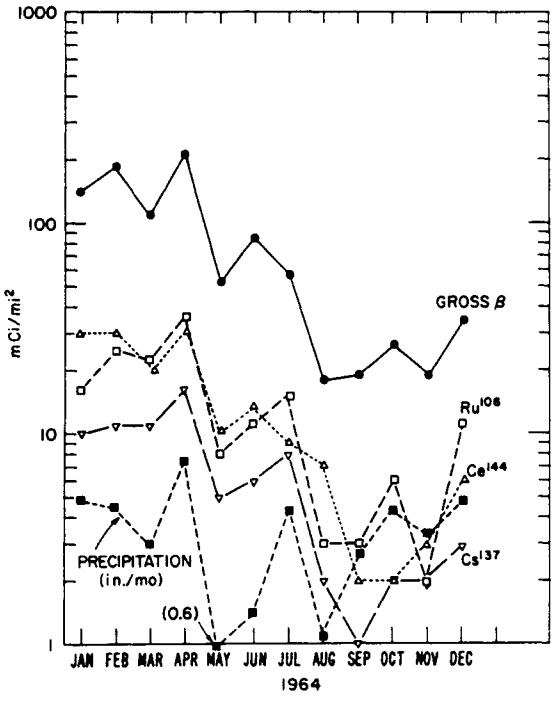

Figure 10. Monthly precipitation collection, gross β activity, and Ce^{144}, Ru^{108}, Cs^{137}, and Zr^{95}-Nb^{95} concentrations.

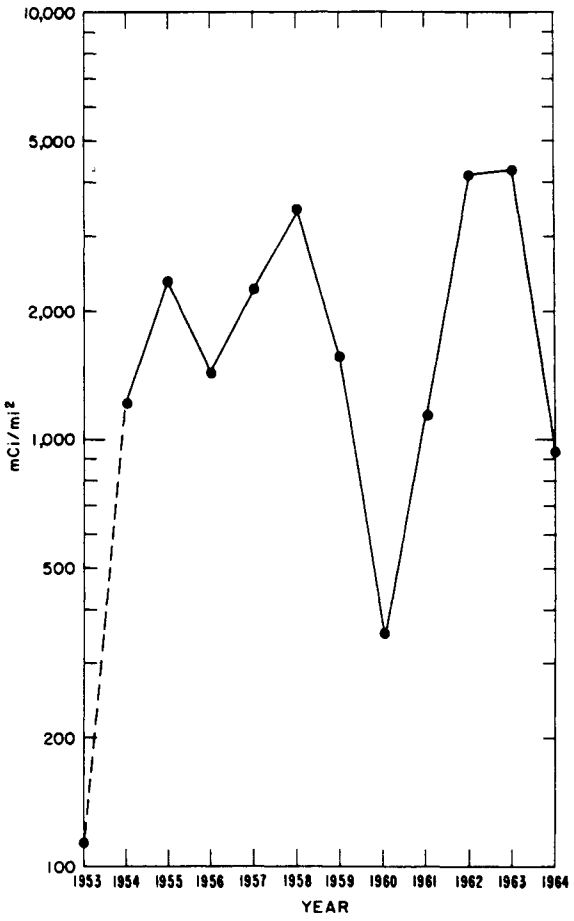

Figure 11. Yearly total gross β activity in rain and settled dust collections, 1953-1964.

LIQUID EFFLUENT MONITORING

Low-level radioactive liquid effluents are routinely disposed of by release into the Laboratory's sanitary waste system, where they are diluted by a large volume of uncontaminated water. This liquid waste effluent passes through an Imhoff tank which removes most of the solids and then flows onto sand filter beds from which most of it is collected by an underlying tile field. The liquid effluent is then chlorinated and discharged into a small stream that forms one of the headwaters of the Peconic River.

Table

1964 BNL Environmental Monitoring, Total Gross β Activity, and Princi

Month	Precipitation, in.	Av conc., pCi/liter	Gross β, mCi/mi^2	Mn^{54}
Jan.	4.9	574	141	3
Feb.	4.5	661	186	4
Mar.	3.0	446	109	5
Apr.	7.5	402	210	5
May	0.6	1150	53	2
June	1.4	928	86	3
July	4.4	207	57	3
Aug.	1.1	195	18	3
Sept.	2.7	91	19	2
Oct.	4.3	75	26	1
Nov.	3.3	83	19	1
Dec.	4.8	70	34	1
Total	42.5	-	938	33
Av	3.6	339	78	3

*Estimated.

The monitoring arrangements for the central sewage system are indicated in Figure 12. Values of the monthly average gross β concentration and total gross β activity 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 15. A calculated radiation protection standard concentration of 1070 pCi/liter, which assumes a 20% Sr^{90} content, is applied at the boundary.

A γ spectrum and a Sr^{90} analysis were performed on a monthly composite of the filter bed input samples and of the effluent from the beds. The concentrations of the principal γ emitters, Cs^{137}, Ce^{144}, and Co^{60}, and of Sr^{90} are indicated in Table 16. I^{131}, Ru^{106}, and Na^{24} were occasionally detected, but generally in concentrations too small for satisfactory quantitative determination. Tritium assays were also made on the daily chlorine house sample from March through September. The results, all below the lower limit of detection: 10^4 pCi/liter for the March-July samples and 5×10^3 pCi/liter for the August and September ones.

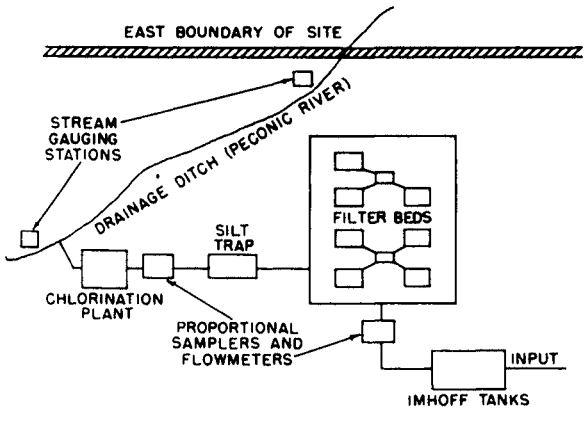

Figure 12. BNL sewage processing and monitoring system.

13

Monthly Average Gross β Concentration, pal Isotope Activities in Precipitation

Sr^{89}	Sr^{90}	Zr^{95}-Nb^{95}	Ru^{106}	Sb^{125}	Cs^{137}	Ce^{144}
6	5	16	16	4	10	30
9	7	20	25	5	11	30
3	5	8	22	4	11	20
<1	11	7	36	7	16	31
N.A.	N.A.	1	8	1	5	10
<1	3	3	11	2	6	13
<1	4	<1	15	3	8	9
N.A.	N.A.	<1	3	2	2	7
<1	<1	<1	3	3	1	2
N.A.	N.A.	<1	6	1	2	2
N.A.	N.A.	<1	2	<1	2	3
<1	<1	<1	11	1	3	6
16*	40*	55	158	33	77	166
1*	3*	5	13	3	6	14

N.A. = not available.

The annual amounts of radioactivity released as liquid waste by the Laboratory have decreased during recent years. Information extracted from BNL internal reports concerning the gross β activity in liquid effluent entering the sand filter beds and discharged from them since 1951 is summarized in Table 17. A shock absorber effect is apparent in the 2-yr delay between the 1959 peak of the input to the beds and the 1961 peak of discharge activity. The yearly amounts of Sr^{90} activity present in liquid effluent samples since 1961 and those of other principal isotopes present since 1962 are shown in Table 18.

About a ton of dried sludge previously pumped from the Imhoff tank was disposed of at the BNL dump in October 1964. The concentrations of the principal γ-emitting isotopes and the estimated total activities are indicated in Table 19.

Although the sand filter beds are reported[11] to be about 90% efficient for most isotopes, their efficiency for Na^{24} appears to be much lower. Between 1800 and 1900 on November 20, 1964, about 1.9 mCi of Na^{24} passed the Imhoff monitor. After correcting for decay, it was determined that 1.3 mCi had passed through the beds by the time the routine sample was picked up at the chlorine house at 0830 on November 21.

STREAM SAMPLING

Monthly "grab" water samples were obtained at on-site and off-site locations along the upper tributary of the Peconic River, into which the Laboratory routinely discharges low-level liquid wastes. Reference grab samples were obtained from nearby streams and bodies of water outside the Laboratory's drainage area. The sampling locations (see Figure 13)

Table

BNL Environmental Monitoring, Monthly Average Gross β

Month	1953	1954	1955	1956
Jan.	—	38.4	4.9	82.2 (N)*
Feb.	—	7.2	57.4 (N)	103
Mar.	— (N)	106 (P)	1210 (N)	105 (R)
Apr.	— (N)	87.9 (P)	641 (N)	105 (R)
May	— (N)	31.0 (P)	346 (N, P)	125 (N, P)
June	— (N)	21.7 (P)	36.5 (	32.6 (N, P)
July	—	17.2	9.7	212 (N)
Aug.	— (R)	48.8	22.4 (R)	62.0 (N, R)
Sept.	14.8	468	8.4 (R)	427 (P, R)
Oct.	10.1 (P)	180 (R)	12.5 (R)	49.1 (P, R)
Nov.	1.5	276	13.8 (R)	32.0 (R)
Dec.	11.3	50.4	12.0	105.0
Total		1332.6	2374.6	1439.9

*Reported Nuclear Detonations: N - U.S., Nevada Test Site; P - U.S. or British, Sahara Test Site.

are as follows:

A. Peconic River at Schultz Road, 15,900 ft downstream from chlorine house.
B. Peconic River at Wading River-Manorville Road, 23,100 ft downstream from chlorine house.
C. Peconic River at Manorville, ≈35,500 ft downstream from chlorine house.
D. Peconic River at Calverton, ≈46,700 ft downstream from chlorine house.
E. Peconic River, upstream from BNL effluent outfall.
F. Peconic River at north tributary (independent of BNL drainage).
G. Carman's River at Middle Island.
H. Carman's 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, 1300 ft below BNL effluent outfall.
M. Peconic River, 2600 ft below BNL effluent outfall (at BNL boundary).
Q. Peconic River, 6900 ft downstream from BNL effluent outfall.

Gross β concentrations found in stream water samples during 1964 are summarized in Table 20. To facilitate comparisons, the samples are tabulated in two groups, one comprising locations in sequence from upstream to downstream on the Peconic River and the other control locations. In September 1964 routine monthly samples were initiated at location Q on the bend of the Peconic adjacent to North Street, about a mile below the Laboratory boundary. Off-site stream sampling was initiated in 1960, and yearly averages since that time are also shown in Table 20. There appears to be relatively little dilution by tributaries in the upper reaches of the stream. Two spot measurements made by the Water Resources Division of the U.S. Geological Survey[1,2] during 1964 indicated that the Peconic River flow at Schultz Road (sam-

14

Activity in Rain and Settled Dust Collections, 1953-1961, mCi/mi^2

1957	1958	1959	1960	1961
348 (R)	102	208	8.1	2.3
36.6 (R)	18.4 (R)	232	270 (S)	3.5
58.5 (R)	144 (R)	535	3.8 (S)	9.2
285 (R)	435 (N, P)	311	9.8	275
112 (N, P)	246 (N, P)	85.4	10.4	19.2
38.8 (N, P)	101 (N, P)	152	10.6	5.0
262 (N)	245 (N, P)	19.2	5.2	5.8
331 (N, R)	197 (N, A, P)	14.5	2.0	9.2
726 (N, P, R)	59.6 (N, A, R)	2.6	15.6	100 (R)
112 (N, P, R)	1109 (N, R)	6.5	11.2	180 (R)
44.3 (P, R)	356 (R)	4.9	2.4	416
97.4 (N, R)	224	3.9	2.0 (S)	372
2138.4	3237.0	1575.0	351.1	1397.2

Pacific Test Site; R - U.S.S.R., site unknown; A- U.S., Atlantic Test Site; S - France,

pling location A) was about three times that at the perimeter (sampling location M), while continuous flow measurements made at the Riverhead Gaging station, near the mouth of the river, averaged 2×10^7 gal/day, about 27 times that at the perimeter. However, the fraction of the gross β concentration in downstream water samples attributable to the BNL effluent appears to fall off quite rapidly in these upper reaches and is not perceptible beyond eight miles or so downstream (between sampling points C and D).

A limited program of stream bottom sampling in the Peconic River was initiated during 1963. In order to obtain a profile of the distribution of radioactivity along the river downstream from the chlorine house outfall, larger numbers of sediment and underwater vegetation samples were obtained during 1964. The samples were not processed except for being packaged for analysis of γ-emitting isotopes. The yearly averages for all sediment samples obtained at a given location are indicated in Figure 14, and those for all vegetation samples in Figure 15. Most of the Laboratory's liquid effluent activity appears to be retained within a short distance downstream from the point of release. The only effluent isotopes detectable above background in the sediment were Co^{60}, Cs^{137}, and Ce^{144}. Small concentrations of fallout-produced Mn^{54} were found in a few samples. The highest concentration of Co^{60}, 11.2 pCi/g, was found 5200 ft downstream from the outfall at the chlorine house; that of Cs^{137}, 6.89 pCi/g, at 6900 ft downstream; and that of Ce^{144}, 1.34 pCi/g, at the outfall. Co^{60} was not detectable beyond 3 miles downstream, and both Cs^{137} and Ce^{144} diminished to near background levels beyond this distance. The underwater vegetation profile was similar, but the concentrations of fallout Mn^{54} were more evident. The highest concentrations of Co^{60} and Ce^{144}, 34.3 pCi/g and 13.3 pCi/g, respectively, were found at the site boundary 2600 ft downstream from the chlorine house; the highest concentration of Cs^{137}, 3.99 pCi/g, at 6900 ft downstream. The

Table 15

1964 BNL Environmental Monitoring
Monthly Average Liquid Effluent Concentration and Total Gross β Activity

Month	Imhoff tank			Chlorine house			Site boundary		
	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.	580,000	111	7.5	458,000	96	5.1	833,000	53	5.1
Feb.	608,000	89	6.3	499,000	102	6.0	641,000	79	6.0
Mar.	713,000	103	8.1	570,000	100	6.3	693,000	83	6.3
Apr.	783,000	76	7.0	662,000	61	4.8	935,000	43	4.8
May	878,000	126	12.6	692,000	116	9.1	1,044,000	77	9.1
June	903,000	109	10.6	685,000	138	11.1	739,000	128	11.1
July	935,000	60	6.4	728,000	83	6.9	736,000	82	6.9
Aug.	952,000	57	6.4	764,000	76	6.8	808,000	72	6.8
Sept.	923,000	59	6.4	796,000	61	5.7	814,000	60	5.7
Oct.	833,000	90	8.5	719,000	72	5.9	730,000	71	5.9
Nov.	801,000	52	5.4	596,000	59	4.1	599,000	59	4.1
Dec.	704,000	50	4.0	613,000	67	4.7	759,000	54	4.7
Total	-	-	89.2	-	-	76.5	-	-	76.5
Av	802,000	80	-	640,000	86	-	766,000	72	-
Estimated error		±15	±1.0	-	±15	±1.0	-	±15	±1.0

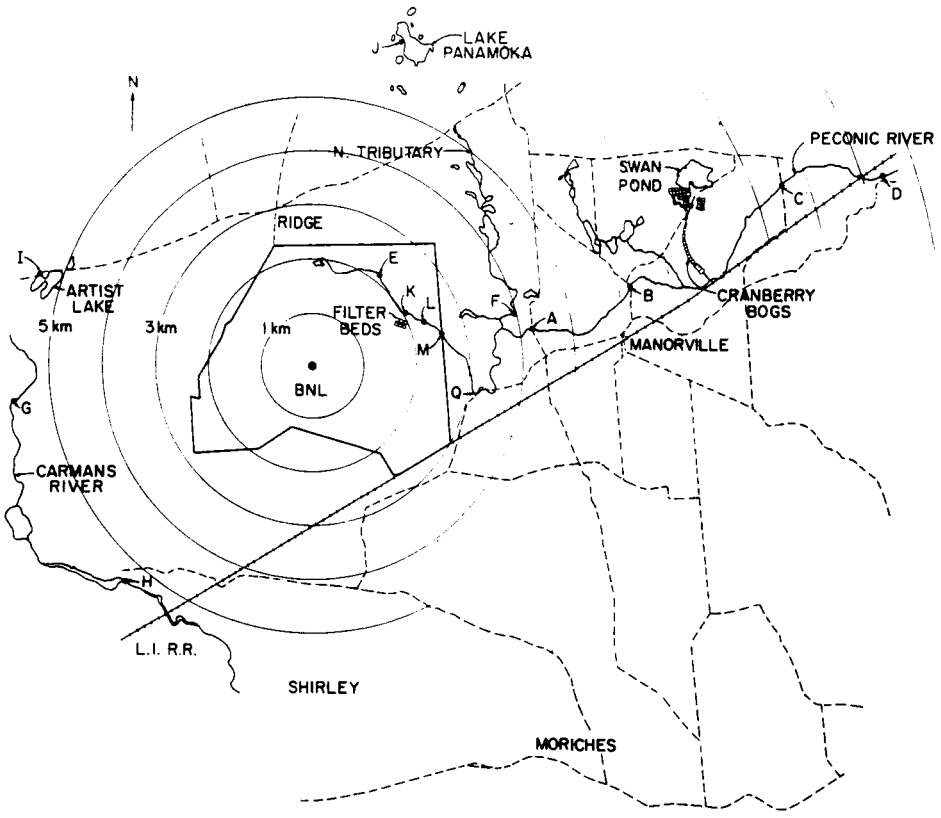

Figure 13. Environmental monitoring stream sampling locations.

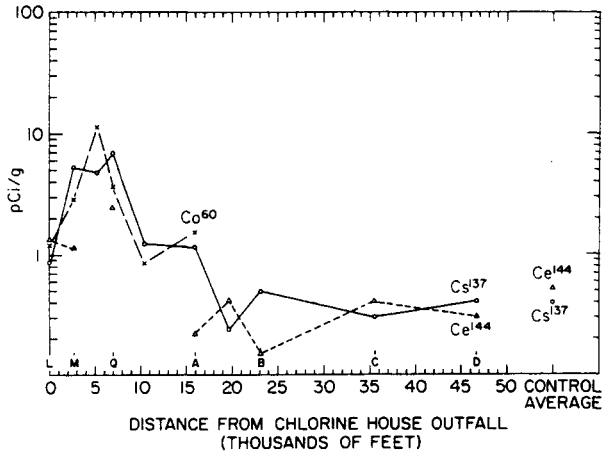

Figure 14. Peconic River sediment samples, 1964.

Table 16

1964 BNL Environmental Monitoring
Liquid Effluent Concentrations and Total Activities of Identifiable γ-Emitting Isotopes and Sr^{90}, pCi/liter

	Imhoff tank				Chlorine house			
Month	Cs^{137}	Co^{60}	Ce^{144}	Sr^{90}	Cs^{137}	Co^{60}	Ce^{144}	Sr^{90}
Jan.	8	55	< 10	2	53	25	< 10	6
Feb.	8	51	55	2	29	45	48	5
Mar.	< 5	39	< 10	4	13	< 5	54	11
Apr.	5	32	48	2	21	18	30	7
May	6	75	19	4*	36	55	33	8*
June	4	20	19	3	27	37	24	6
July	11	< 5	40	4	49	29	< 10	3
Aug.	5	< 5	37	5	46	16	< 10	5
Sept.	11	< 5	< 10	2	28	< 5	15	4
Oct.	12	< 5	< 10	1	20	< 5	< 10	3
Nov.	< 5	< 5	< 10	1	15	<5	< 10	2
Dec.	14	< 5	< 10	1	60	23	< 10	3
Av, pCi/liter	8	22	21	3	43	19	18	5
Total, mCi	8.7	24.5	23.2	2.9	38.4	17.5	16.6	4.7

*Estimated concentration, sample not run for Sr^{90}.

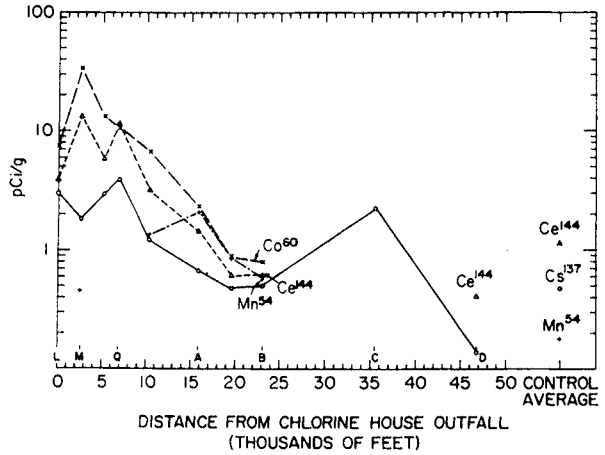

Figure 15. Peconic River vegetation samples, 1964.

Table 17

BNL Enviromental Monitoring
Gross β Activity in Liquid Effluent,
1951-1964, mCi

Year	Imhoff tank	Chlorine house
1951	160.5	21.5
1952	116.6	27.9
1953	132.9	35.8
1954	182.1	48.5
1955	223.8	75.0
1956	170.0	55.0
1957	300.8	105.1
1958	325.1	106.0
1959	586.6	169.5
1960	542.9	177.8
1961	384.4	219.1
1962	128.9	135.9
1963	127.5	99.4
1964	89.0	76.4
Total	3471.1	1352.9

distribution of Mn^{54} was more random, and the highest concentration, 2.09 pCi/g, was found 15,900 ft downstream. Two sunfish obtained during June near sampling location D, 46,700 ft downstream, contained an average of 1.57 pCi/g of Cs^{137}. No other γ-emitters were detectable in them.

Since there is an abundant underground supply of water on Long Island, the Peconic River is not used to supply drinking water or water for irrigation. Its waters are occasionally used to flood the lower bogs of a commercial cranberry operation eight miles downstream. In the fall of 1964, samples of berries from the upper and lower bogs of this farm and of berries of other-than-local origin were obtained. As indicated in Table 21, no effect attributable to the use of river water in the lower bog was discernible.

WELL SAMPLING

The Laboratory's potable water wells and cooling water supply wells are about 100 ft deep, or 50 ft below the water table in the Long Island surface layer of glacial till. They are also generally west to northwest and upstream from most of the Laboratory's facilities. 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 (see Figure 16). Monthly gross β results are summarized in Table 22. Less than background values (< 1.2) have been assumed to be 50% of the detection limit in calculating yearly averages. No significant differences from previous sampling are apparent.

MILK SAMPLING

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

The results of a routine monthly sampling program are indicated in Table 23. 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. The applicable Radiation Protection Guide[13] for I^{131} assuming an intake of 1 liter/day, is 100 pCi/liter.

Shortly after the peak on October 28 of air particulate activity attributable to the Chinese weapons test, measurable concentrations of I^{131} were found in the milk from two locations in the vicinity of BNL. These locations were resampled at intervals until the concentrations reached the lower limit of detection. The highest were found in the milk from a one-cow farm where the animal was free to eat *ad lib* on

Table 18

BNL Environmental Monitoring
Activity of Principal Isotopes in Liquid Effluent, 1961-1964

Year	Gross β, mCi	Cs^{137} mCi	Cs^{137} % of gross β	Ce^{144} mCi	Ce^{144} % of gross β	Co^{60} mCi	Co^{60} % of gross β	Sr^{90} mCi	Sr^{90} % of gross β
				Imhoff tank					
1961	384.4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	39.4	10.3
1962	128.9	20.4	15.8	12.1	9.4	<5	<4	16.2	12.6
1963	127.5	20.4	16.0	21.7	17.0	21.6	17.0	7.7	6.0
1964	89.0	8.7	9.8	23.2	26.0	24.5	27.5	2.9	3.3
				Chlorine house					
1961	219.1	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	38.0	17.4
1962	135.9	54.6	40.0	9.3	6.8	<5	<4	19.2	14.1
1963	99.4	44.8	45.1	13.5	13.6	18.3	18.4	7.7	7.8
1964	76.4	38.4	50.3	16.6	21.8	17.4	22.8	4.7	6.2

N.A. = not available.

Table 19

1964 BNL Environmental Monitoring
Concentrations and Total Activities in Sludge From Imhoff Tank, Oct.

	Co^{60}	Cs^{137}	Ce^{144}	Gross β
Average concentration of eight drying beds, pCi/g	320	160	157	517
Estimated total activity, mCi	0.32	0.16	0.16	0.52

a thin stand of winter rye. As shown in Figure 17, if the greater weight is given to the early samples of higher concentration (and accuracy of measurement), the data suggest a 4.8-day effective half-life of I^{131} in milk from a single incident of pasture contamination.

VEGETATION AND SOIL SAMPLING

In June and September pasture grass samples were gathered at the farms from which monthly milk samples were obtained. Occasional samples were obtained in other months, in particular during late

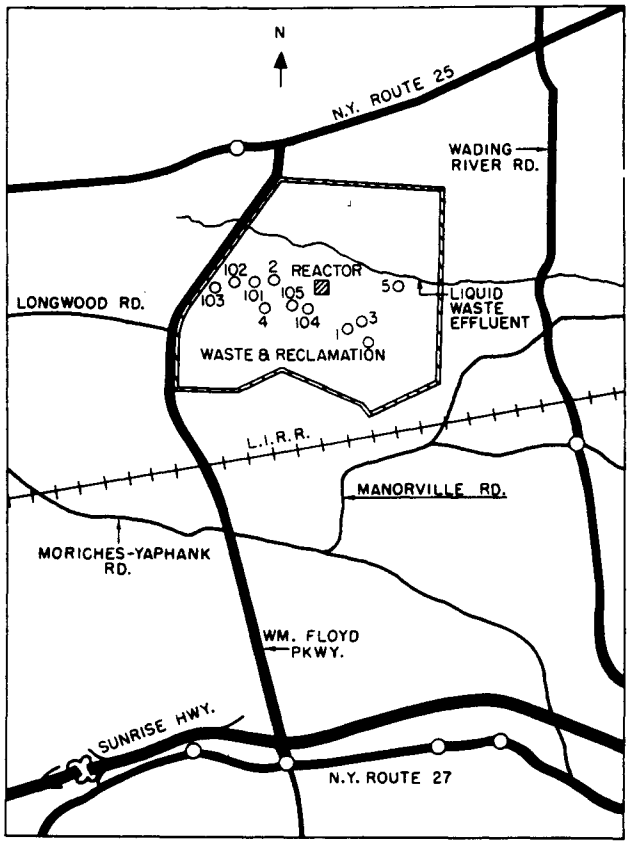

Figure 16. Location of BNL water supply wells.

October and early November following the detection of airborne activity from the first Chinese weapons test. As indicated in Table 24, a summary of the concentrations of γ-emitting isotopes present in these samples, no activity uniquely attributable to the BGRR stack emission was detectable.

During the two weeks after the well-defined peak of fallout air particulate activity on October 28, concentrations of I^{131} between 0.1 and 0.3 pCi/g were measured. Since there was no precipitation for some time after the 28th, it was possible to calculate a deposition velocity for I^{131} of $0.25 \pm {}^{0.15}_{0.10}$ cm/sec for a set of observations on November 1st.

Samples of the top 6 in. of soil were also obtained in June and September from the farms in the vicinity of the Laboratory from which vegetation samples were secured. The concentrations of identifiable γ-emitting isotopes present are given in Table 25. The concentrations of natural uranium and thorium are determined by comparison with the γ spectrum of calibrated ore samples.

ON-SITE SUMPS

Monitoring for the possible entry of radioactivity into the ground water was extended to include three recharge basins, one north of the Alternating Gradient Synchrotron, one east of the BGRR, and one south of the Medical Center, into which secondary cooling water from these facilities is discharged. These sumps are also open to surface runoff and, as shown in

Table 20

1964 BNL Environmental Monitoring
Monthly Stream Water Samples and Yearly Averages for 1960-1964,
Gross β Concentrations in pCi/liter

	Peconic River locations, proceeding downstream from chlorine house								Control locations					
	K	L	M	Q	A	B	C	D	E	F	G	H	I	J
Month, 1964														
Jan.	97	81	76	-	46	22	21	24	Dry	27	13	21	23	35
Feb.	75	74	73	-	20	58	16	18	Dry	21	19	11	33	27
Mar.*	41	37	35	-	24	17	17	17	20	12	12	9	39	17
Apr.	23	21	15	-	28	24	21	21	18	17	25	28	25	18
May	491	216	76	-	25	37	24	19	17	26	7	9	24	24
June	94	85	81	-	49	23	24	14	4	21	8	4	19	13
July	199	168	19	-	35	19	22	12	Dry	17	7	13	19	16
Aug.	39	30	32	-	26	19	18	10	Dry	16	6	3	31	14
Sept.	84	81	19	44	22	12	10	9	Dry	11	17	6	18	9
Oct.*	52	58	36	40	28	18	16	9	18	18	7	4	21	14
Nov.	-	-	-	-	-	-	-	-	Dry	-	-	-	-	-
Dec.	74	60	74	72	31	23	18	-	Dry	32	22	6	25	12
Yearly av														
1964	115	83	49	52	30	25	19	14	15	19	13	10	25	18
1963	61	74	39	-	46	42	59	40	36	37	13	25	50	35
1962	-	-	-	-	47	31	39	33	38	35	23	36	44	38
1961	-	-	-	-	34	19	-	17	17	10	6	9	14	16
1960	-	-	-	-	20	13	-	11	8	5	7	9	13	6

Estimated error: <25 pCi/liter, ± 3; >25 pCi/liter, ± 10%.
*These samples were also analyzed for tritium. All results were <5 nCi/liter.

Table 26, appear to follow the concentration trends in the streams reported in the section on stream sampling.

THYROID SAMPLING

One cattle thyroid was obtained from Farm *A*, 3 km northwest of the BGRR stack, on March 10, 1964. It contained 25 ± 10 pCi of I^{131}. An analysis of meteorological data for the preceding few weeks suggests that this location was downwind during a period of precipitation on March 3 in which 29 pCi/m^2 was calculated to have been deposited by "rainout" at Farm *A*. The animal had been grazing on a very scant covering of winter rye between March 3 and 10. Another beef thyroid obtained on June 24 from an experimental research animal at the Brookhaven Medical Department contained 5 ± 5 pCi of I^{131}.

A number of thyroids from deer killed on the public highways in the vicinity of the Laboratory were obtained through the

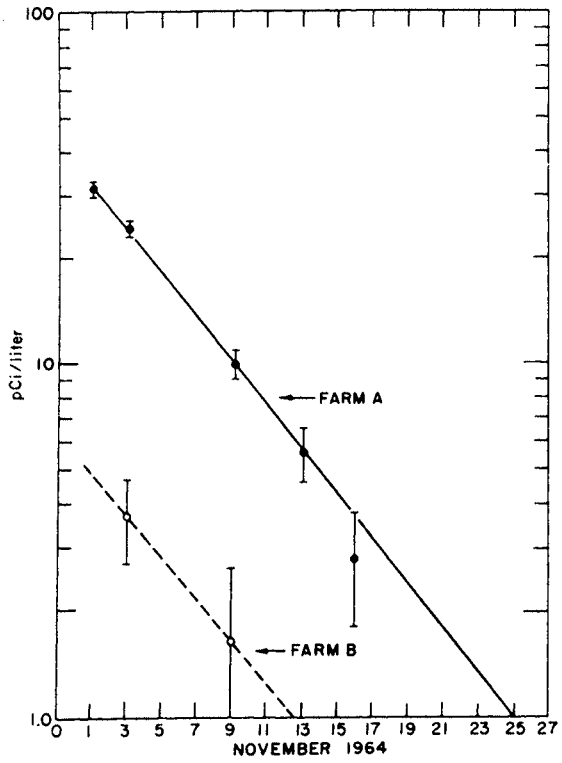

Figure 17. I^{131} in milk samples, Nov. 1964.

Table 21

1964 BNL Environmental Monitoring
Concentrations of γ-Emitting Isotopes in Cranberries, pCi/g

	Date counted	Cs^{137}	Mn^{54}
Upper bog, Manorville	11/28	1.0	0.1
Lower bog, Manorville	11/28	1.0	0.1
Nonlocal	10/12	1.0	0.1
Estimated error		± 0.2	± 0.1

Table 22

1964 BNL Environmental Monitoring
Gross β Concentrations in Deep Well Water Samples, pCi/liter

	Potable water well no.						Cooling supply well no.				
Month	1	2	3	4	5	W&R*	101	102	103	104	105
Jan.	5.5	4.1	< 1.2	6.8	1.8	< 1.2	< 1.2	7.6	1.7	< 1.2	2.9
Feb.	4.7	3.8	5.8	3.1	2.9	4.5	-	5.4	2.1	2.1	-
Mar.	4.7	2.2	-	3.3	6.2	4.4	-	3.4	3.6	5.4	-
Apr.	2.8	2.9	-	2.1	6.1	1.6	3.3	4.8	5.1	-	7.6
May	6.3	5.0	3.5	8.9	6.0	3.4	-	7.0	5.3	14.4	17.6
June	1.3	1.9	2.1	4.3	5.6	1.7	-	1.5	< 1.2	-	2.2
July	1.2	< 1.2	1.5	2.7	6.0	2.6	1.1	-	1.8	1.8	4.2
Aug.	1.4	< 1.2	4.5	1.3	2.5	3.9	1.7	1.0	1.7	< 1.2	< 1.2
Sept.	1.7	1.2	2.1	1.9	2.2	2.2	< 1.2	0.2	< 1.2	< 1.2	< 1.2
Oct.	< 1.2	1.9	< 1.2	1.4	2.5	< 1.2	-	-	-	3.0	2.1
Nov.	3.6	4.6	3.0	5.7	3.0	-	-	-	-	1.6	< 1.2
Dec.	5.1	< 1.2	1.3	2.4	3.6	< 1.2	5.0	2.4	< 1.2	-	1.4
Av	3.1	2.2	2.3	3.6	4.0	2.0	1.6	3.7	2.0	2.9	3.6

*Waste disposal and reclamation well.

Table 23

1964 BNL Environmental Monitoring, Concentrations of I^{131}, Cs^{137} and K in Milk Samples
(values for K in g/liter; all others in pCi/liter)

Routine Monthly Samples

	Farm *A*, 3 km NW			Farm *B*, 6 km SW			Farm *C*, 10 km SE			Farm *D*, 15 km NW		
Month	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K
Jan.	255	<10	1.4	176	< 10	1.9	226	< 10	1.4	156	< 10	1.6
Feb.	-	-	-	-	-	-	312	< 10	1.3	153	< 10	1.6
Mar.	-	-	-	113	< 10	1.6	190	< 10	1.4	120	< 10	1.7
Apr.	-	-	-	135	< 10	1.7	269	< 10	1.5	181	< 10	1.7
May	177	<10	1.3	110	< 10	2.1	132	< 10	1.4	129	< 10	1.4
June	-	-	-	-	-	-	86	< 10	1.4	140	< 10	1.1
July	164	<5	1.5	93	< 5	1.9	125	3	1.1	-	-	-
Aug.	-	-	-	99	3	1.3	111	< 3	1.2	-	-	-
Sept.	90	<10	1.6	97	< 10	1.6	142	< 10	2.0	104	< 10	2.1
Oct.	123	<10	1.7	79	< 10	1.3	171	< 10	1.8	114	< 10	1.6
Nov.	85	15	1.6(5)[a]	107	5	1.7(3)	133	5	1.6(2)	96	5	1.6
Dec.	-	-	-	119	< 1	1.7	128	< 1	1.1	91	< 1	1.2
Av	123	9	1.6	112	3	1.7	166	4	1.4	128	5	1.6

Special Samples

	Farm *E*, 8 km E			Farm *F*, 8 km ENE			Farm *G*, 5 km ESE		
	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K	Cs^{137}	I^{131}	K
July	238	< 3	2.0	121	< 10	1.7	-	-	-
Aug.	85	< 1	1.5	167	< 10	1.9	-	-	-
Sept.	147	< 10	1.2	206	< 10	1.4	-	-	-
Oct.	134	< 10	2.1	-	-	-	-	-	-
Nov.	-	-	-	-	-	-	230	6	1.2
Dec.	-	-	-	89	< 1	1.4	-	-	-
Av	151	3	1.7	146	4	1.6	230	6	1.2

[a] No. of samples.

Table 24

1964 BNL Environmental Monitoring
Concentrations of γ-Emitting Isotopes in Pasture
Grass During the Growing Season, Wet Weight
(values for K in g/kg; all others in pCi/g)

Location	Month	Mn^{54}	Zr^{95}-Nb^{95}	Ru^{106}	Cs^{137}	Ce^{144}	K
Farm *A*, 3 km NW	June	0.5	<0.5	1.3	0.7	3.7	-
	July	6.2	<0.5	<0.5	2.2	3.9	-
	Sept.	<0.5	<0.5	1.8	1.1	8.5	16.8
	Oct.	<0.5	<0.5	0.6	1.3	0.8	4.4
	Nov.	<0.5	<0.5	1.9	0.7	2.6	6.7
Av		3.7	<0.5	1.2	1.2	3.9	9.3
Farm *B*, 6 km SW	May	<0.5	<0.5	<0.5	<0.5	0.6	8.1
	June	<0.5	<0.5	<0.5	0.9	2.4	-
	July	<0.5	<0.5	<0.5	<0.5	0.8	4.2
	Aug.	<0.5	<0.5	<0.5	<0.5	2.0	10.3
	Sept.	0.6	<0.5	1.3	0.8	2.1	-
	Oct.	<0.5	<0.5	1.5	<0.5	<0.5	6.7
	Nov.	<0.5	<0.5	1.6	<0.5	1.6	5.9
Av		<0.5	<0.5	0.8	0.5	1.5	6.5
Farm *C*, 10 km SE	June	<0.5	2.3	6.1	5.1	22.4	-
	Sept.	<0.5	<0.5	<0.5	0.5	<0.5	-
	Nov.	<0.5	<0.5	1.5	0.5	2.6	3.2
Av		<0.5	0.9	2.6	2.0	8.3	3.2
Farm *D*, 15 km NW	June	<0.5	<0.5	1.3	0.9	2.9	-
	Sept.	<0.5	<0.5	0.7	0.6	1.9	-
Av		<0.5	<0.5	1.0	0.8	2.4	-
Farm *E*, 8 km E	July	<0.5	<0.5	<0.5	<0.5	1.2	-
	Sept.	0.7	<0.5	1.1	1.1	2.6	8.8
	Nov.	<0.5	<0.5	2.1	0.6	3.0	12.3
Av		<0.5	<0.5	1.7	1.0	2.3	11.1
Farm *H*, 6 km NE	June	<0.5	<0.5	<0.5	0.5	1.8	-
	Sept.	2.6	<0.5	1.8	2.7	8.2	12.0
Av		1.4	<0.5	1.0	1.6	5.0	12.0

Table 24 (continued)

1964 BNL Environmental Monitoring
Concentrations of γ-Emitting Isotopes in Pasture
Grass During the Growing Season, Wet Weight
(values for K in g/kg; all others in pCi/g)

Location	Month	Mn^{54}	Zr^{95}-Nb^{95}	Ru^{106}	Cs^{137}	Ce^{144}	K
Farm *I*, 30 km ENE	June	0.9	0.7	<0.5	2.3	4.9	6.7
	Sept.	<0.5	<0.5	0.7	<0.5	1.1	9.9
Av		0.6	0.5	0.5	1.3	3.0	8.3
On site stations							
E-9	July	0.6	<0.5	0.6	<0.5	0.8	N.A.
E-5	Oct.	0.5	<0.5	<0.5	0.6	3.2	18.0
E-9	Nov.	0.7	<0.5	2.5	0.6	1.6	4.4
E-11	Nov.	<0.5	<0.5	1.3	<0.5	1.3	5.8
Av		0.5	<0.5	1.2	<0.5	1.7	9.4
Over-all monthly av							
1[a]	May	<0.5	<0.5	<0.5	<0.5	0.6	8.1
6	June	<0.5	0.7	4.7	1.7	6.4	6.7
4	July	1.8	<0.5	<0.5	1.5	1.7	4.2
1	Aug.	<0.5	<0.5	<0.5	<0.5	2.0	10.3
7	Sept.	0.7	<0.5	1.1	1.1	3.5	6.8
3	Oct.[b]	<0.5	<0.5	0.8	0.7	1.4	9.7
6	Nov.[c]	<0.5	<0.5	1.9	0.5	2.1	6.4
1964 Av		<0.5	<0.5	1.7	1.1	3.2	6.8

Estimated error of individual samples, miminum detectable or 25%.

[a] No. of samples.
[b] I^{131} av, 0.15 pCi/g.
[c] I^{131} av, 0.17 pCi/g.

Table 25

1964 BNL Environmental Monitoring
Concentrations of γ-Emitting Isotopes in Soil
(values for K in g/kg; all others in pCi/g)

Location	Month	Mn^{54}	Ru^{106}	Cs^{137}	Ce^{144}	U_{nat}	Th_{nat}	K
Farm *A*	June	<0.2	0.3	0.6	1.6	2.2	2.7	4.6
	Sept.	<0.2	0.3	0.5	1.8	2.0	2.7	6.2
Farm *B*	June	<0.2	0.4	0.5	1.3	1.7	2.6	4.7
	Sept.	<0.2	0.8	0.9	1.9	3.4	4.3	8.7
Farm *C*	June	<0.2	0.2	0.5	1.3	2.0	2.4	5.7
	Sept.	<0.2	<0.2	1.1	1.0	1.9	2.6	3.9
Farm *D*	June	<0.2	<0.2	0.8	2.0	2.8	3.4	6.5
	Sept.	0.8	1.2	1.8	3.9	2.3	4.1	5.3
Farm *E*	Sept.	<0.2	0.6	1.0	2.0	1.5	2.3	3.1
Farm *H*	June	<0.2	0.4	0.3	1.9	1.7	2.0	3.5
	Sept.	0.2	0.7	0.7	1.4	1.7	2.7	4.9
Farm *I*	June	<0.2	<0.2	<0.2	<0.2	3.2	3.8	10.2
	Sept.	<0.2	<0.2	0.4	1.0	4.3	9.7	10.7
Over-all av		<0.2	0.4	0.7	1.6	2.4	3.5	6.0
Estimated error*		±0.2	±0.2	±0.2	+0.2	±0.5	±0.5	±1.0

*Individual sample.

cooperation of the New York State Department of Conservation. The amounts of I^{131} and Cs^{137} found are shown in Table 27.

MISCELLANEOUS

During mid-1964, a cooperative program with the Medical Department was initiated to gather data for a comparison of whole-body burdens and 24-hr urine sample levels of Cs^{137}. During the third quarter the average Cs^{137} burden of 18 randomly selected Laboratory employees was 16.3 mCi, while their 24-hr urine samples averaged 187 ± 15 pCi in a concentration of 134 ± 10 pCi/liter. During the fourth quarter the average Cs^{137} burden of eight different employees was 18.0 nCi, and their 24-hr urine samples averaged 139 ± 15 pCi in a concentration of 126 ± 10 pCi/liter.

Table 26

1964 BNL Environmental Monitoring
Gross β Concentrations in Recharge Basins, pCi/liter

Month	Location		
	North of AGS	East of BGRR	South of Medical Center
Jan.	21	3	16
Feb.	19	3	6
Mar.	15	20	3
Apr.	15	10	-
May	36	33	33
June	14	18	3
July	7	2	2
Aug.	7	1	4
Sept.	11	5	5
Oct.	13	15	2
Nov.	-	-	-
Dec.	5	<2	3
Av	15	10	9

Estimated error, ±10% if >±1 pCi/liter.

Table 27

1964 BNL Environmental Monitoring
I^{131} and Cs^{137} in Deer Thyroids

Location	Date	Thyroid weight, g	I^{131}, pCi	Cs^{137}, pCi
Ridge	6/13	5.8	5	25
Calverton	7/3	2.7	17	13
Calverton	7/3	4.3	3	8
Calverton	8/25	4.1	<3	27
BNL perimeter	10/23	N.A.	46	N.A.
BNL perimeter	10/23	N.A.	5	N.A.

N.A. = not available.

ACKNOWLEDGMENTS

The assistance of Messrs. E. Hartmann and J. M. Gilmartin, Mrs. J. Nobile, and the late Mrs. C. T. Tiffany in the collection and processing of the data is gratefully acknowledged. Strontium and tritium analyses were performed by the Health Physics Division's Analytical Chemistry Section headed by J. R. Steimers. Meteorological consultation and cooperation in the joint I^{131} monitoring program was provided by the Meteorological Group headed by M. E. Smith. The Cs^{137} whole-body and urine level study was carried on with the cooperation of S. M. Cohn of the Medical Department. S. Becker of the Suffolk County Health Department collected many of the off-site milk and vegetation samples.

REFERENCES

1. A.P. HULL, *1962 Environmental Radiation Levels at Brookhaven National Laboratory,* BNL 807 (T-310), May 1963.
2. A.P. HULL, *1963 Environmental Radiation Levels at Brookhaven National Laboratory,* BNL 915 (T-376), Nov. 1964.
3. J.B.H. KUPER and R.L. CHASE, A monitor for low intensity gamma-rays, *Rev. Sci. Instr.* 21, 356-9 (1950).
4. U.S. Atomic Energy Commission, *Standards for Radiation Protection,* Chapter 0524, AEC Manual, 1963.
5. F.P. COWAN and C.B. MEINHOLD, *Radiation Botany* 2, 241-9 (1962).
6. C.F. FOELIX and A.P. HULL, Monitoring the cooling air effluent from the Brookhaven Graphite Research Reactor at the point of release and in the environment, in *Intern. Colloq. Radioactive Pollution of Gaseous Media, Saclay, Nov. 1963,* Vol. II, pp. 449-54, Centre d'Etudes Nucléaires, Saclay, France, 1965.
7. M.E. SMITH, *Seasonal Concentrations at Health Physics Monitoring Stations From BGRR,* memorandum to A.P. Hull, Feb. 11, 1965.
8. P.W. KREY and W.C. ROSA, *HASL Surface Air Sampling Program Gamma Activity Measurements for November 1964,* Health and Safety Laboratory, US AEC, New York, March 8, 1965.
9. A.P. HULL and M.E. SMITH, *An Evaluation of the Environmental Significance of a Postulated Fuel Element Failure at the Brookhaven Graphite Research Reactor,* BNL 819 (T-318), June 1963.
10. M. EISENBUD, *Environmental Radioactivity,* Table 14-1, McGraw-Hill, New York, 1963.
11. L. GEMMELL, Efficiency of filter beds for treating radioactive waste, *Nucleonics* 10, No. 10, 40-2 (1952).
12. Water Resources Division, U.S. Geological Survey (Albany, N.Y.), *Surface Water Records of New York, 1964.*
13. Federal Radiation Council, *Staff Report 2, Background Material for the Development of Radiation Protection Standards,* Sept. 1961.

☆ GPO—J 955-623