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ENVIRONMENTAL RADIOACTIVITY AT
ARGONNE NATIONAL LABORATORY

Report for the Year 1956

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I. SUMMARY

Concentrations of radioactivity in several types of samples obtained from the ANL site and from locations approximately 10, 25, and 100 miles from the Laboratory are given in this report. The sampling locations are shown in Figures 7 and 8. Since ANL waste water is discharged into Sawmill Creek, which in turn empties into the Des Plaines River, special emphasis was placed on sampling these streams. Most of the results were obtained by counting the total alpha and beta activities after suitable preparation of the samples. Some of the samples were also analyzed for specific elements and nuclides. The average total activities in water, bottom silt, surface soil, and plants during 1956 are shown in Figures 1 and 2. The average activities in these types of samples from 1952 through 1956 are compared in Figures 3 through 6.

Radioactive contamination due to ANL operations was found in water and bottom silt from Sawmill Creek below the Laboratory waste water outfall. The total alpha activity in water from this location averaged $11.8 \mu\mu\text{c}/1$, or about $8 \mu\mu\text{c}/1$ higher than water collected upstream from the outfall. Corresponding differences in earlier years ranged from about 7 to $27 \mu\mu\text{c}/1$. The additional alpha activity below the outfall was due primarily to normal uranium in Laboratory waste water. Approximately 95% of the below-outfall samples that were analyzed for uranium contained above normal concentrations of this element, and about 90% of the total alpha activity in these samples was due to uranium. The average uranium concentration in these samples was $17.4 \mu\mu\text{c}/1$, or about 0.025% of the maximum permissible concentration (MPC) for water given in NBS Handbook 52. The maximum uranium concentration found below site this year was $96 \mu\mu\text{c}/1$, or about 0.14% of the MPC. Plutonium was also found in some of the below-outfall water samples. Since it was not detected above the outfall, the plutonium was apparently added to the stream in ANL waste water. About one half of the below-outfall samples that were analyzed for plutonium contained more than the detection limit of $0.2 \mu\mu\text{c}/1$. The average plutonium concentration in these samples was $7 \mu\mu\text{c}/1$, or about 0.5% of the MPC; the highest concentration, $46 \mu\mu\text{c}/1$, was 3% of the MPC for plutonium.

Figure 1

AVERAGE RADIOACTIVITY IN WATER AND BOTTOM SILT, 1956

Micromicrocuries per Liter or Gram

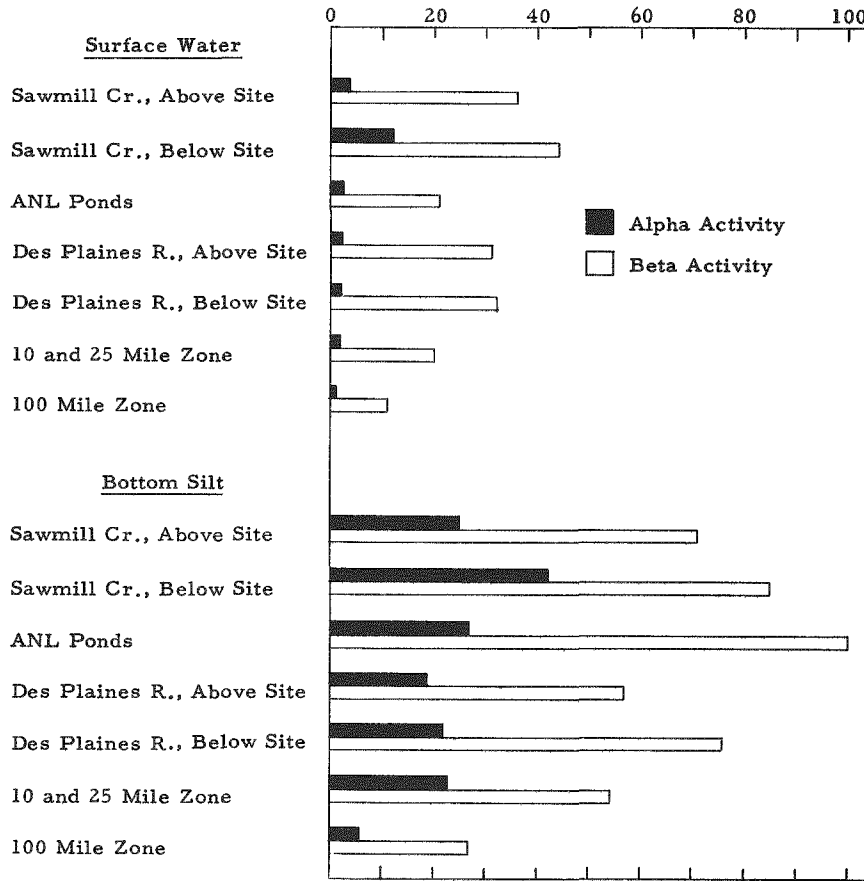


Figure 2

AVERAGE RADIOACTIVITY IN SOIL AND PLANTS, 1956

Micromicrocuries per Gram

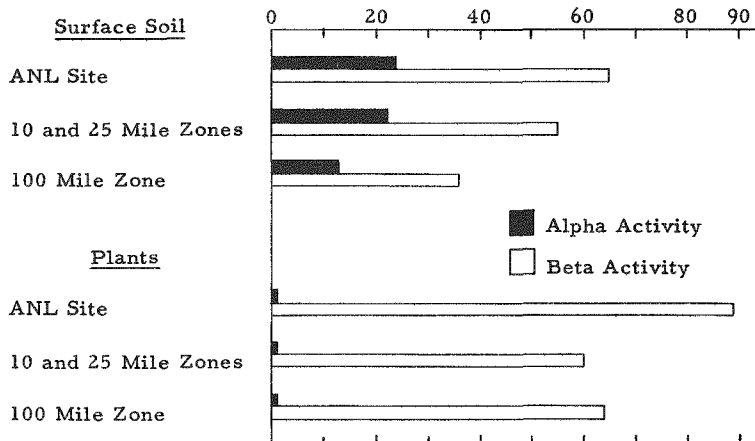


Figure 3

AVERAGE RADIOACTIVITY IN SURFACE WATER, 1952-56

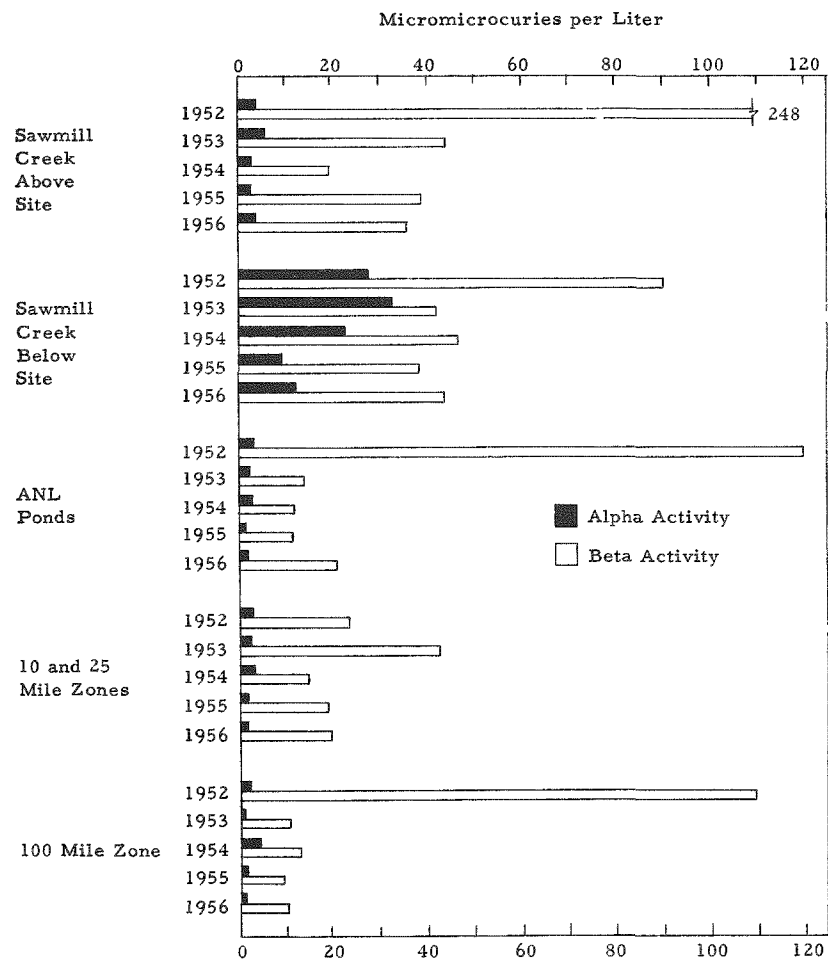


Figure 4

AVERAGE RADIOACTIVITY IN BOTTOM SILT, 1952-56

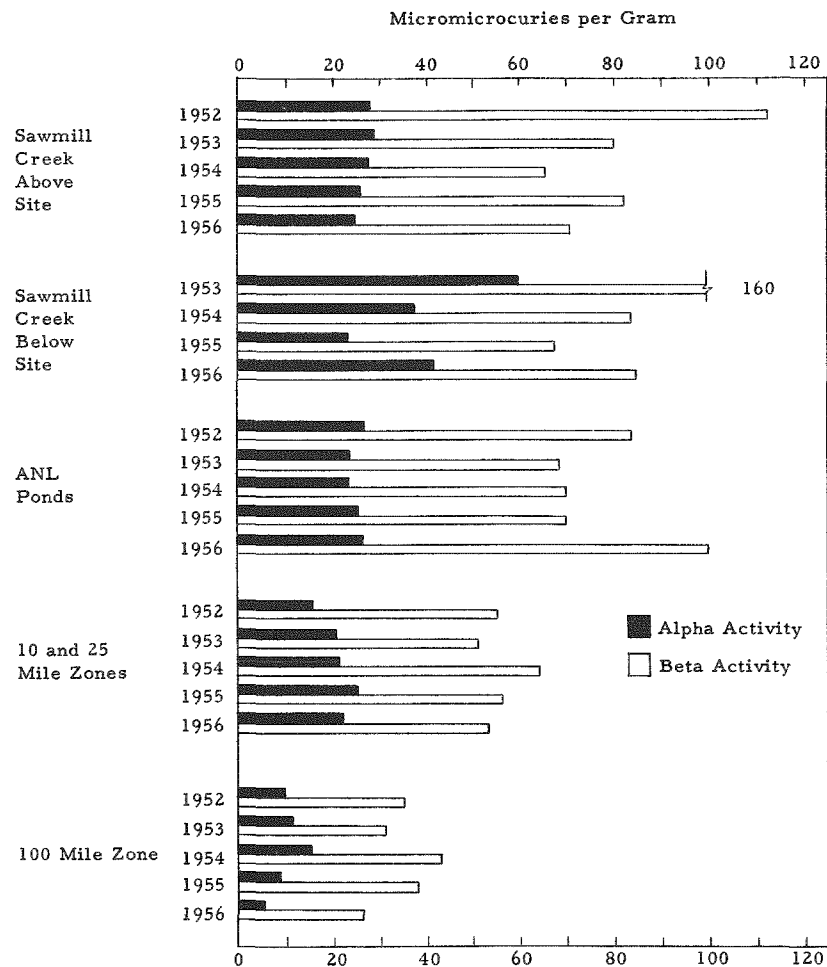


Figure 5

AVERAGE RADIOACTIVITY IN SURFACE SOIL, 1952-56

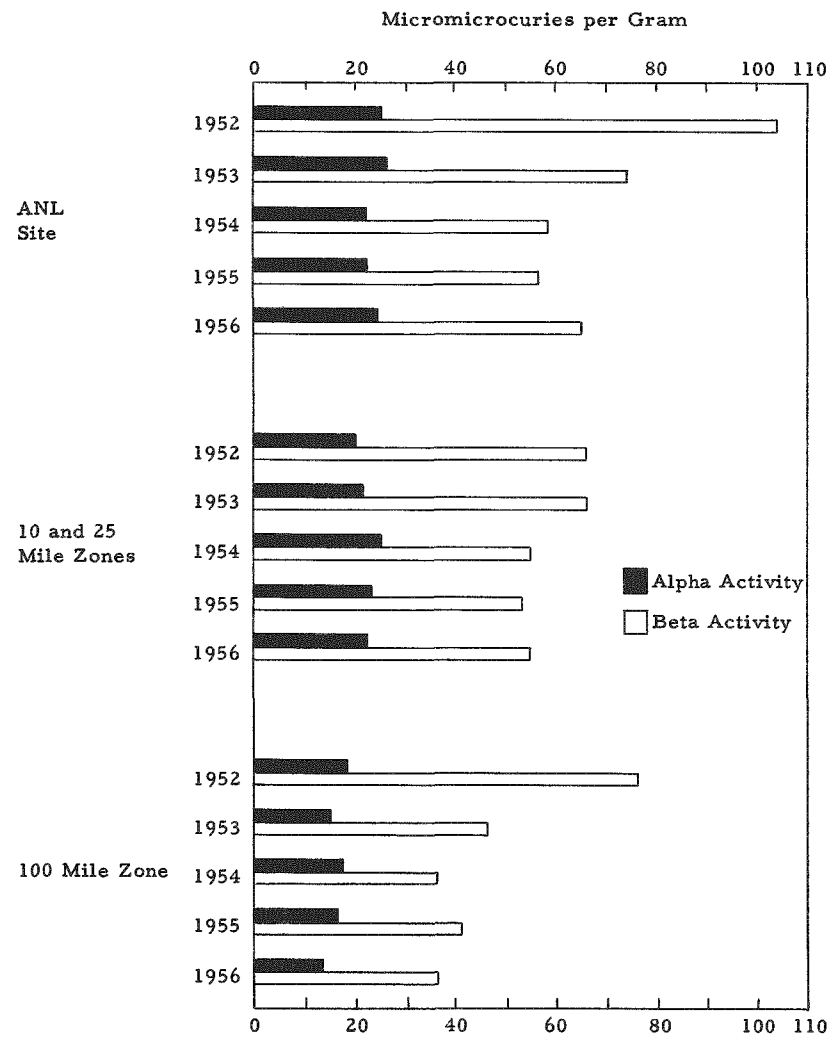
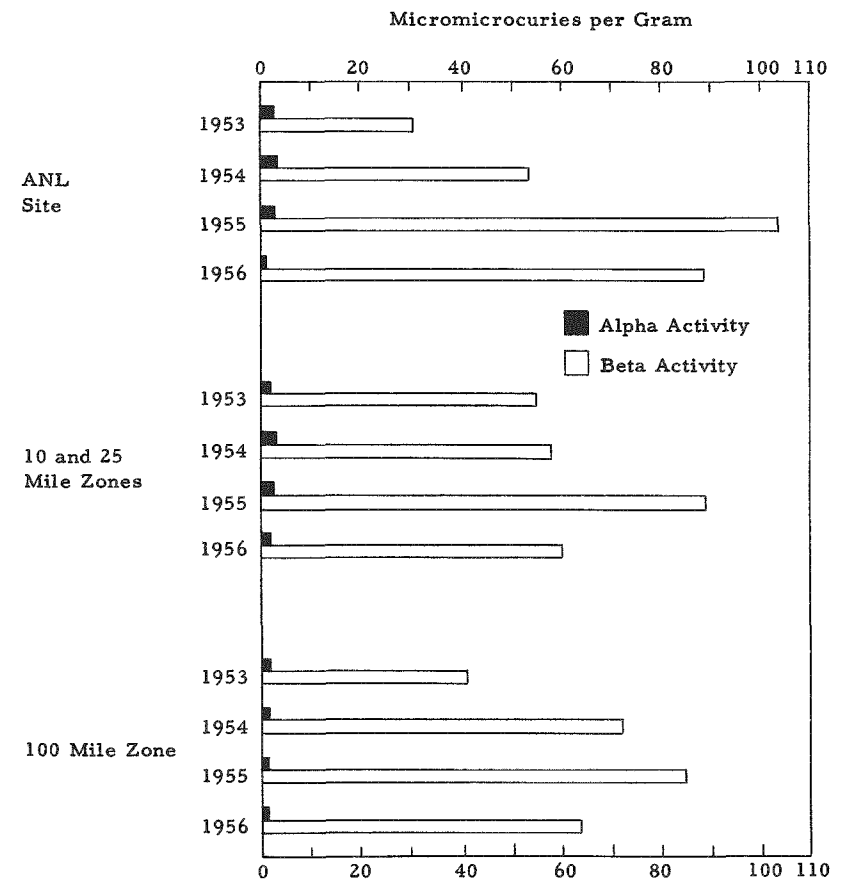


Figure 6

AVERAGE RADIOACTIVITY IN PLANTS, 1953-56



Beta emitters derived from both fission product fallout and Laboratory waste water were found in Sawmill Creek water. Fallout activity was detected from February to September, and contributed an average of about $20 \mu\mu\text{c}/1$ to the Creek during this period. The beta activity added to the Creek in Laboratory waste water was due to fission products and the UX_1 and UX_2 daughters of uranium. The activity added to the Creek from this source usually ranged from 5 to $25 \mu\mu\text{c}/1$. No hazardous concentrations of individual fission products were detected in the Creek, although several individual samples contained total beta activities in excess of $100 \mu\mu\text{c}/1$, the MPC for unknown beta activity given in Handbook 52. The activity in these samples was derived from both of the sources given above.

The activity added to Sawmill Creek in ANL waste water and fallout had no detectable effect on the radioactivity in the Des Plaines River. The total alpha activity (about $2 \mu\mu\text{c}/1$), uranium concentration ($1.3 \mu\mu\text{c}/1$), and total beta activity (about $31 \mu\mu\text{c}/1$) were essentially the same both above and below the mouth of Sawmill Creek.

No abnormal concentrations of radioactivity were found in any of the other natural bodies of water on the ANL site. The concentrations of alpha activity in water from these sources varied from 1 to $3.5 \mu\mu\text{c}/1$; the corresponding values for beta activity were 11 to $33 \mu\mu\text{c}/1$. Water samples collected within twenty-five miles of the Laboratory contained similar concentrations of radioactivity. The average activities in water from the reference sites (100 miles from the Laboratory), $1.7 \mu\mu\text{c}\alpha/1$ and $10.5 \mu\mu\text{c}\beta/1$, were very similar to the averages obtained for the same locations during the previous three years.

Concentrations of total activity in bottom silt showed wide variations with location and time of sampling. The increased activity added to Sawmill Creek in Laboratory waste water was reflected in increased activity in some of the bottom silt obtained from the Creek below the waste water outfall. These individual samples contained two to three times the normal values for Sawmill Creek bottom silt, about 25 and $70 \mu\mu\text{c}/\text{g}$ of alpha and beta activity, respectively. The average concentrations of total activity in bottom silt obtained above the water outfall were $25 \mu\mu\text{c}\alpha/\text{g}$ and $71 \mu\mu\text{c}\beta/\text{g}$, as compared with average values of $42 \mu\mu\text{c}\alpha/\text{g}$ and $85 \mu\mu\text{c}\beta/\text{g}$ below the waste water outfall.

The alpha activity in samples of bottom silt from the Des Plaines River was essentially the same above and below the mouth of Sawmill Creek, averaging about $20 \mu\mu\text{c}/\text{g}$ at both locations. The total beta activity averaged $57 \mu\mu\text{c}/\text{g}$ above and $76 \mu\mu\text{c}/\text{g}$ below the mouth of Sawmill Creek. This difference in the average values for the year resulted from significant

increases (25 to 65 $\mu\mu\text{c/g}$) below the mouth of the Creek in three of the samples collected during the year. Since these samples were collected during periods of high fission product fallout, the most likely source of this increased activity was localized accumulation of fallout activity, rather than Laboratory waste water. Contamination resulting from Laboratory waste water would probably cause increases in both alpha and beta activity, as was observed in Sawmill Creek.

The alpha activity in bottom silt from the natural ponds on the ANL site averaged 27 $\mu\mu\text{c/g}$ and was normal and similar to that found in bottom silt within 25 miles of the Laboratory. The beta activity was normal in April and July, about 70 $\mu\mu\text{c/g}$, but increased to about 150 $\mu\mu\text{c/g}$ in October, apparently due to fallout.

Borings collected from the bottom of the storage lagoon for contaminated waste water on the ANL Site showed a large accumulation of activity in the upper two inches of material. The upper layer contained about 400 $\mu\mu\text{c}\alpha/\text{g}$ and 3000 $\mu\mu\text{c}\beta/\text{g}$. Below two inches the borings contained normal concentrations of activity, 27 to 40 $\mu\mu\text{c}\alpha/\text{g}$ and 61 to 96 $\mu\mu\text{c}\beta/\text{g}$.

The alpha and beta activities in bottom silt from the reference sites were about 30% lower than in 1955, and averaged 6 $\mu\mu\text{c}\alpha/\text{g}$ and 27 $\mu\mu\text{c}\beta/\text{g}$.

The average concentrations of alpha and beta activities in soil from all locations were similar to those found in other years. There was no significant difference between samples collected on the ANL site and from locations within 25 miles of the Laboratory. As was observed in other years, soil from the reference sites averaged 30 to 40% lower than soil obtained from the other locations, and this is attributed to the predominance of sandy soil samples from the reference sites.

The total alpha activities in grass samples were essentially the same at all locations, about 1 $\mu\mu\text{c/g}$. The total beta activities averaged 15 to 30 $\mu\mu\text{c/g}$ lower than samples from the same locations in 1955, indicating a reduced amount of fallout in grass samples during 1956. Grass from the ANL site contained an average of 89 $\mu\mu\text{c}\beta/\text{g}$ and off-site grass samples contained about 62 $\mu\mu\text{c}\beta/\text{g}$, although the same range of activities was found both on and away from the ANL site. The difference in the average is attributed to differences in the amount of fallout activity at various times and locations.

Concentrations of long-lived alpha and beta activities in air filter samples collected on the ANL site from 1953 through 1956 are also given. Individual samples were collected for a 24-hour period, and the total

activity was determined from the counting rate of the filter paper three days after the end of the filtering period. The total alpha activity remained quite uniform, averaging 0.03 micromicrocuries per cubic meter ($\mu\mu\text{c}/\text{m}^3$) for each year. Monthly averages varied from 0.01 to 0.06 $\mu\mu\text{c}/\text{m}^3$. This long-lived alpha activity is attributed primarily to natural activities present in dust in the air.

The beta activity remaining in the air filter samples after three days of decay was primarily due to fission products from nuclear detonations. From 1953 through 1955 monthly averages of beta activity varied from 0.1 to 0.5 $\mu\mu\text{c}/\text{m}^3$ during periods of little fallout to 1 to 8 $\mu\mu\text{c}/\text{m}^3$ during periods of bomb testing. During 1956 the minimum value increased to 0.9 $\mu\mu\text{c}/\text{m}^3$, probably because nuclear detonations were carried out over a longer period of time than in previous years. In general, the increased beta activity was observed during the spring and fall of each year. The annual average beta activity varied from 0.5 $\mu\mu\text{c}/\text{m}^3$ in 1954 to 1.6 $\mu\mu\text{c}/\text{m}^3$ in 1956.

II. PROCEDURES

This report presents the results of the environmental monitoring program at Argonne National Laboratory for the year 1956 as well as some of the results obtained in earlier years for air samples. The purposes of the program are to detect increases in the radioactive content of the ANL site and environs and to determine the causes of any such increases. The nature of the program is indicated by Table I, which gives the number and types of samples collected in 1957.

TABLE I
SAMPLES COLLECTED IN 1957

Water	268	Bottom Silt	121
Rain	156	Plant	65
Soil	82	Animal	15
		Air Filter	596

Samples were collected from the Argonne site and from locations approximately 10, 25, and 100 miles from the Laboratory. The sampling locations are given in Figures 7 and 8. The locations 100 miles from the Laboratory are referred to as reference sites.

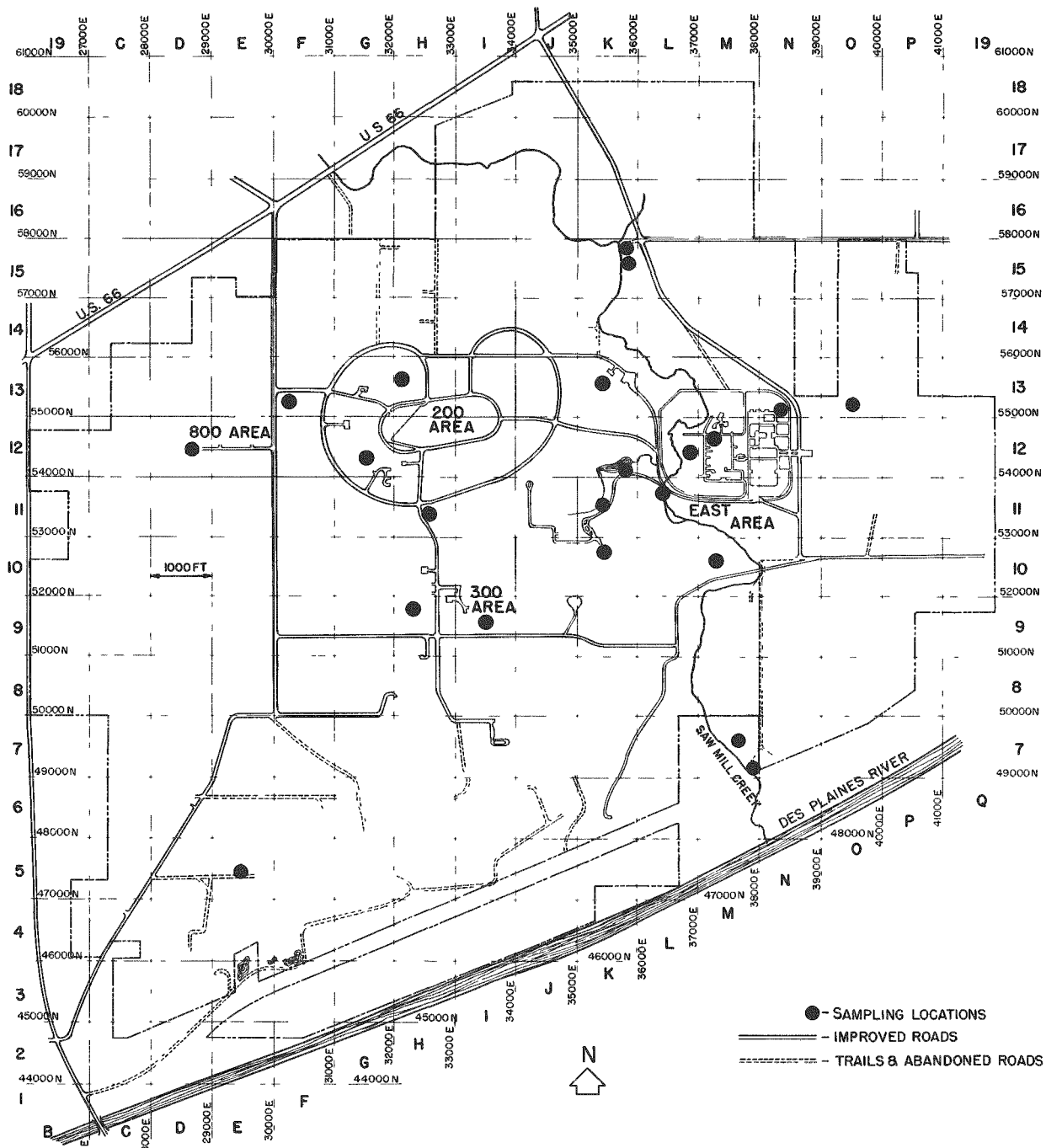


FIGURE 7
SAMPLING LOCATIONS ON SITE OF ARGONNE NATIONAL LABORATORY

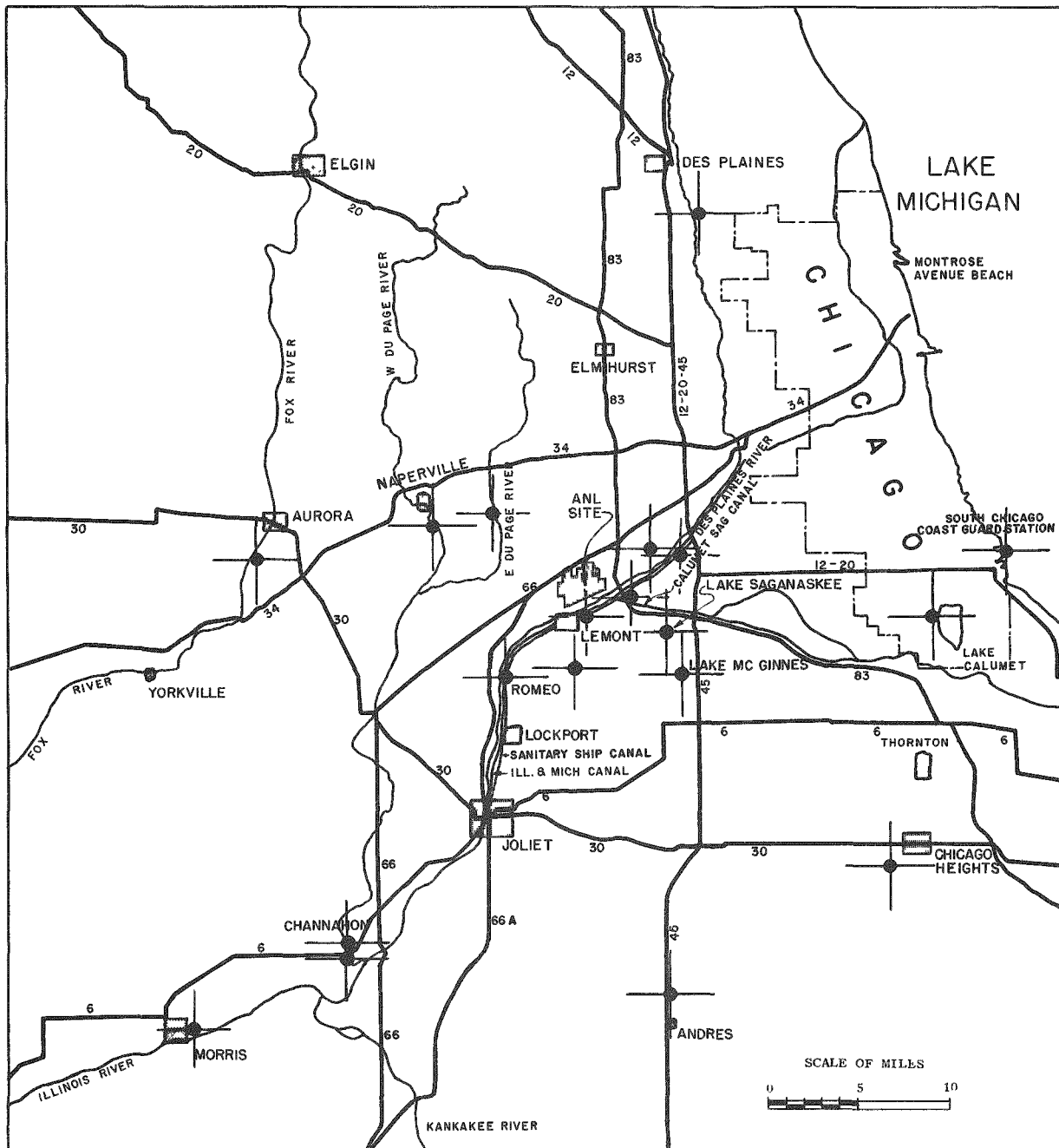


FIGURE 8
SAMPLING LOCATIONS NEAR ARGONNE NATIONAL LABORATORY

Most of the samples were analyzed for total alpha and beta activity by direct counting after suitable preparation of the sample. The counting rates were converted to micromicrocuries by applying corrections measured for Pu^{239} (for alpha particles) and Tl^{204} (for beta particles). Some of the samples were also analyzed for specific elements and nuclides. Approximately 10% of the samples were not analyzed, but were stored for future use.

The sampling program, counting techniques, and most of the analytical procedures are given in detail in the previous reports in this series: ANL-5069, ANL-5289, ANL-5446, and ANL-5684.

The following procedure was used during 1956 for plutonium and thorium analyses of water. A one-liter portion of water was evaporated to dryness, the residue leached with 0.1M HNO_3 , and any insoluble material removed by centrifugation. The solution was made 2M in nitric acid, sulfurous acid added, and the plutonium and thorium coprecipitated with cerium fluoride. The fluoride precipitate was dissolved in aluminum nitrate solution, the plutonium reduced with hydroxylamine, and the thorium extracted into a benzene solution of thenoyltrifluoroacetone (TTA). The aluminum nitrate solution was then made 0.1M in potassium dichromate, 0.7M in nitric acid, and heated at 90°C for one hour to oxidize the plutonium. The solution was then cooled and the plutonium extracted into ethyl ether. For ease in mounting the plutonium and thorium fractions, and to obtain additional separation from uranium, the extracted activities were re-extracted into nitric acid solution and coprecipitated with cerium fluoride. The fluoride precipitates were mounted on stainless steel and counted. The plutonium recovery for each sample was determined by analyzing a second portion of the water sample to which a known amount of plutonium had been added. The thorium recovery was not determined for each sample, but was taken as the average of several analyses of water samples containing known amounts of Th^{230} .

III. RADIOACTIVITY IN ENVIRONMENTAL SAMPLES

A. Rain

The total alpha and beta activities in precipitation collected on the Laboratory site are given in Table II. The short-lived alpha activities were due to radon and thoron daughters normally present in air. The alpha activity remaining one week after the end of the rainfall was due to natural activities in dust carried down by the rain or in dust blown into the rain collector. This was indicated by uranium analyses of some of the rain samples and the fact that rain samples containing amounts of long-lived alpha activity above normal also contained large amounts of solids.

TABLE II

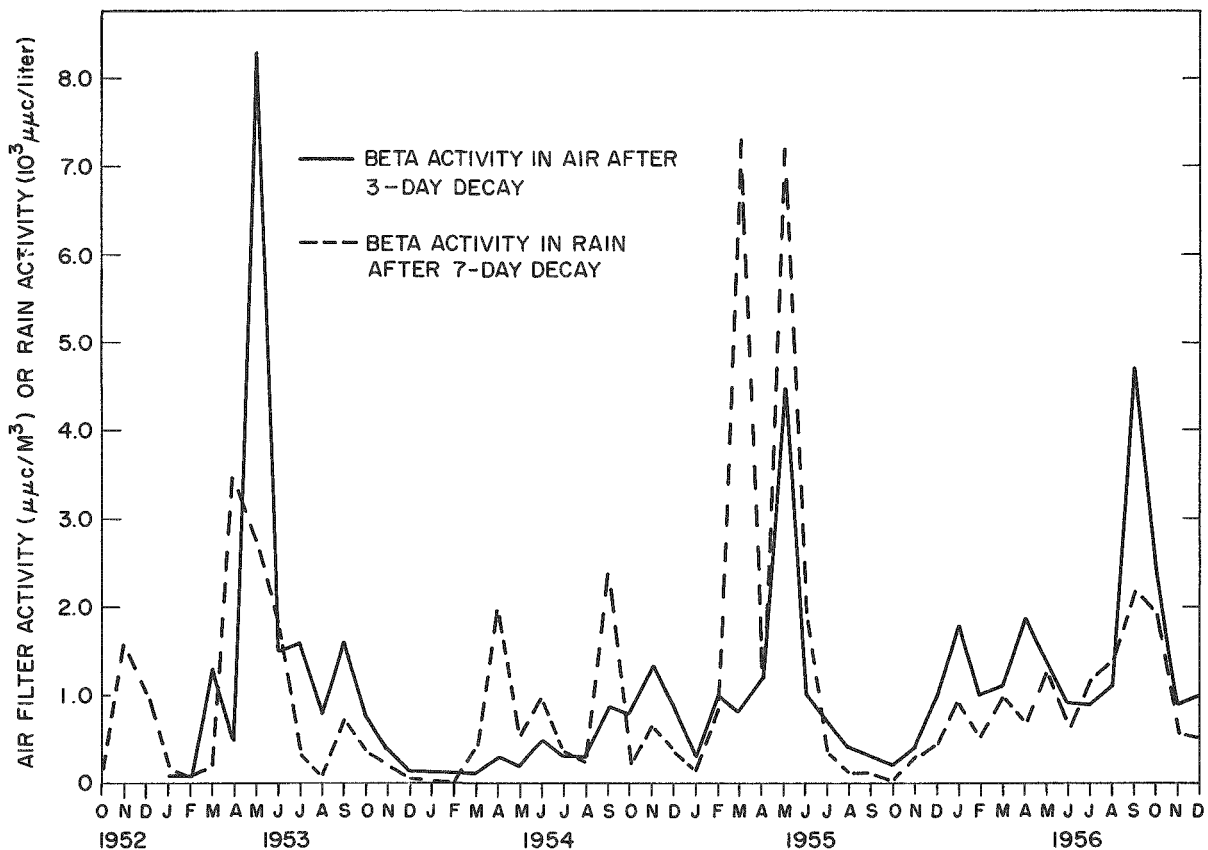
NONVOLATILE RADIOACTIVITY IN RAINWATER AT ANL, 1956

Month	Samples Collected*	Alpha Activity						Beta Activity					
		After 1 Day Decay			After 1 Week Decay			After 1 Day Decay			After 1 Week Decay		
		Samples Counted	$\mu\mu\text{c/liter}$		Samples Counted	$\mu\mu\text{c/liter}$		Samples Counted	$10^2 \mu\mu\text{c/liter}$		Samples Counted	$10^2 \mu\mu\text{c/liter}$	
			Max.	Av.		Max.	Av.		Max.	Av.		Max.	Av.
January	6	6	41.1	12.4	6	20.9	7.4	6	33.0	11.7	6	29.4	9.5
February	9	8	11.4	4.8	9	8.4	3.5	9	9.6	5.5	9	9.1	5.2
March	9	9	27.8	14.8	9	18.7	10.9	9	23.4	11.4	9	20.0	10.3
April	12	12	130.	36.	12	24.0	7.9	12	29.6	7.9	12	27.3	6.9
May	16	14	196.	33.	16	15.4	3.8	14	126.4	17.4	16	86.9	13.3
June	8	6	18.8	5.3	8	6.4	2.5	8	19.8	8.6	8	16.0	6.3
July	17	16	18.0	9.7	17	6.4	1.6	17	43.6	17.9	17	27.9	12.1
August	16	12	32.0	8.7	16	21.0	3.0	15	85.8	16.4	16	69.0	13.9
September	9	7	221.	45.3	9	13.0	2.6	7	45.2	20.9	9	65.6	22.4
October	6	2	13.2	7.8	6	8.8	3.0	2	53.8	31.0	6	28.6	16.5
November	9	5	27.5	13.7	9	24.6	6.1	5	26.6	10.9	9	20.8	5.6
December	8	8	16.0	8.0	8	15.0	5.9	8	10.1	6.5	8	8.5	5.1

*Two successive portions were collected from heavy rains and are considered as separate samples. Each portion was equivalent to 0.1 in. of rain.

The beta activity remaining after one week was largely due to fission products from nuclear detonations. The increases in the monthly averages during the spring and fall months corresponded to announced periods of bomb testing. Fission product concentrations did not show the large fluctuations of previous years. Although no individual sample contained more than $10^4 \mu\mu\text{c}/\text{l}$ (after one week), this is the first year since rain collection was begun that the average monthly beta activity did not drop below $500 \mu\mu\text{c}/\text{l}$ for any month. The general trend of long-lived beta activity in rain is evident from Figure 9, in which the monthly averages of beta activity are plotted for October, 1952 through December, 1956.

FIGURE 9
BETA ACTIVITY IN RAIN AND AIR FILTERS ON ANL SITE, 1953-1956



Some of the rain samples were analyzed for several of the fission products. The results are given in Table III. For a given fission product, the variation in concentration among the samples was an inverse function of its half-life. This is to be expected since all rainwater contained fission products from a large number of detonations occurring at various times. The Sr^{90} concentration showed less variation than the other fission products, indicating a relatively constant source of this nuclide.

TABLE III
FISSION PRODUCT ACTIVITY IN RAINWATER, 1956

Date of Rainfall	Amount (in.)	Total Beta Activity ($10^2 \mu\mu\text{c}/1$ after 1 week decay)	Micromicrocuries Per Liter at End of Rainfall				
			Sr ⁸⁹	Sr ⁹⁰	Ba ¹⁴⁰	Ce ¹⁴¹	Ce ¹⁴⁴
March 27-28	0.28	20.0	183	13	92	390	81
April 2	0.02	27.3	--	--	--	45	158
April 25	0.42	9.7	139	15	12	51	103
May 9-10 (First portion)	1.33	10.4	209	7	141	--	--
May 9-10 (Second portion)	1.33	6.2	159	10	123	--	--
May 11	0.1	86.9	915	12	284	898	259
July 31	0.28	27.9	--	--	--	184	63

B. Air Filters

Monthly summaries of air filter samples collected on the ANL site from 1953 through 1956 are given in Tables IV to VII. Most of the individual samples cover a 24-hour period, although a few of the samples were collected for two or three days. Air was monitored continuously during the four-year period, except for the occasional loss of a sample due to equipment failure. Such losses totaled about 25 days during the four-year period.

Air was filtered through Hollingsworth-Vose 70 filter paper using a Filter Queen Vacuum Cleaner (Health-Mor Corp.) modified to draw air through the paper, or a Sutorbilt Air Sampler. A rotameter was used to measure the air flow; the Filter Queen air sampler operated at 15 cubic meters per hour and the Sutorbilt Air Sampler at 30 cubic meters per hour. The area of the paper was 200 cm². After the sampling period the paper was sprayed with a solution of polystyrene in ethylene dichloride to fix the particulate matter on the paper; the thickness of polystyrene layer was 50 micrograms per cm². A circle two inches in diameter (20 cm²) was cut from the center of the filter paper, mounted on a stainless steel counting planchet and counted for alpha and beta activity in a nylon-window proportional counter. The results given in the tables are based on counts taken approximately three days after the end of the filtering period, in order to allow time for the decay of radon and thoron daughters. The correction factors used to convert the total counting rates to nominal disintegration rates were those measured for the short-lived radon descendants.* It should be emphasized, however, the "third-day"

* These correction factors were determined by Dr. Andrew F. Stehney of the Radiological Physics Division of ANL.

TABLE IV
LONG-LIVED ACTIVITY IN DAILY AIR FILTER
SAMPLES ON ANL SITE, 1953

Month	No. of Samples	Alpha Activity ($\mu\mu\text{c}/\text{m}^3$)		Beta Activity ($\mu\mu\text{c}/\text{m}^3$)	
		Max.	Av.	Max.	Av.
January	26	0.05	0.02	0.14	0.08
February	26	0.03	0.01	0.15	0.07
March	30	0.05	0.01	25.4	1.3
April	27	0.12	0.02	1.2	0.5
May	27	0.11	0.03	127.1	8.3
June	24	0.18	0.03	5.7	1.5
July	25	0.15	0.03	2.7	1.6
August	28	0.14	0.04	5.7	0.8
September	26	0.64	0.05	3.5	1.6
October	28	0.11	0.04	1.5	0.8
November	26	0.12	0.04	0.8	0.4
December	29	0.08	0.01	0.22	0.13
Average		0.03		1.4	

TABLE V
LONG-LIVED ACTIVITY IN AIR FILTER SAMPLES
ON ANL SITE, 1954

Month	No. of Samples	Alpha Activity ($\mu\mu\text{c}/\text{m}^3$)		Beta Activity ($\mu\mu\text{c}/\text{m}^3$)	
		Max.	Av.	Max.	Av.
January	28	0.91	0.02	0.23	0.13
February	28	0.30	0.03	0.67	0.13
March	28	0.02	0.01	0.52	0.12
April	29	0.10	0.02	1.5	0.3
May	30	0.13	0.04	1.0	0.2
June	29	0.13	0.04	1.1	0.5
July	28	0.12	0.03	0.66	0.31
August	30	0.14	0.03	0.70	0.30
September	29	0.45	0.05	7.3	0.9
October	30	0.10	0.02	2.0	0.8
November	28	0.12	0.03	4.7	1.4
December	28	0.07	0.02	2.8	0.9
Average		0.03		0.5	

TABLE VI
LONG-LIVED ACTIVITY IN AIR FILTER SAMPLES
ON ANL SITE, 1955

Month	No. of Samples	Alpha Activity ($\mu\mu\text{c}/\text{m}^3$)		Beta Activity ($\mu\mu\text{c}/\text{m}^3$)	
		Max.	Av.	Max.	Av.
January	27	0.05	0.02	0.7	0.3
February	23	0.02	0.01	5.4	1.0
March	31	0.22	0.02	5.4	0.8
April	30	0.50	0.05	2.8	1.2
May	31	0.08	0.02	48.1	4.5
June	28	0.08	0.02	2.3	1.0
July	29	0.07	0.03	3.6	0.7
August	31	0.25	0.05	1.3	0.4
September	29	0.11	0.03	0.6	0.3
October	29	0.26	0.03	1.7	0.2
November	28	0.12	0.02	3.2	0.4
December	29	0.28	0.02	1.6	0.6
Average		0.03		1.0	

TABLE VII
LONG-LIVED ACTIVITY IN AIR FILTER SAMPLES
ON ANL SITE, 1956

Month	No. of Samples	Alpha Activity ($\mu\mu\text{c}/\text{m}^3$)		Beta Activity ($\mu\mu\text{c}/\text{m}^3$)	
		Max.	Av.	Max.	Av.
January	30	0.04	0.01	1.3	1.8
February	26	0.01	0.01	1.5	1.0
March	29	0.06	0.01	3.7	1.1
April	30	0.08	0.03	6.4	1.9
May	30	0.04	0.01	3.5	1.3
June	30	0.08	0.02	2.0	0.9
July	31	0.08	0.02	2.1	0.9
August	30	0.10	0.03	2.8	1.1
September	27	0.18	0.06	28.0	4.7
October	30	0.10	0.04	5.8	2.4
November	25	0.16	0.04	3.2	0.9
December	27	0.40	0.03	3.4	1.0
Average		0.03		1.6	

activity given in the tables was not due to radon daughters, but was due primarily to fission products (for most of the beta activity) and a mixture of naturally radioactive nuclides present in dust (for the alpha activity and some of the beta activity).

Accurate disintegration rates could not be obtained from the total counting rates for several reasons: The composition of the mixture of nuclides producing the third-day activity was unknown and variable, so that accurate counting efficiencies could not be obtained for each sample. In addition, some of the fission product activity was probably present in a relatively few large particles, while the radon daughters were uniformly distributed on the paper. This could result in a different counting efficiency, particle penetration, and retention for fission products and radon daughters. However, the nominal total disintegration rates have proved useful in the intercomparison of samples and in approximate comparisons between the long-lived activity and radon concentrations in the air.

The beta activity concentrations in Tables IV to VII are plotted in Figure 9. The monthly variations may be correlated with periods of atomic detonations. In general, increases were noted in the spring or summer and in the fall of each year. The principal feature of the data is the sustained increase in beta activity throughout 1956. Prior to 1956 the monthly average fell a few tenths of a micromicrocurie per cubic meter during periods when no bomb testing took place. In 1956 the minimum value was $0.9 \mu\mu\text{c}/\text{m}^3$, or five to ten times the minimum of previous years. However, even during 1956 the average fission product beta activity was only about 1% of the radon daughter beta activity (RaB and C). In spite of the sustained higher levels observed during 1956, the average for the entire year did not show any marked increase, since the unusually high values ($>5 \mu\mu\text{c}/\text{m}^3$) observed for short periods during 1953, 1954, and 1955 were not found in 1956.

Monthly summaries of long-lived beta activity in rain are also plotted in Figure 9 for comparison with air activities. During most of the four-year period, the variations in beta activity in the two types of samples were similar. Notable exceptions occurred in April and May, 1953 and May, 1955. Exact correspondence between the rain and air activities cannot be expected, of course, since the time of the rainfall will greatly influence the activity found in rain.

The monthly variations in long-lived alpha activity did not correspond to those found for beta activity and were evidently caused by variations in the amount of dust in the air. The average alpha activity, $0.03 \mu\mu\text{c}/\text{m}^3$, remained constant over the four-year period.

C. Water

1. Sawmill Creek and Des Plaines River

ANL waste water is discharged into Sawmill Creek, which in turn empties into the Des Plaines River (Figure 7). The amount of activity added to Sawmill Creek in the waste water may be determined by comparing the concentrations of radioactive nuclides in the Creek above and below the ANL waste water outfall. Monthly summaries of the alpha activity from these two sampling locations are given in Table VIII.

The Creek was dry during October, November, December, and part of September. Consequently water was not available upstream from the waste water outfall during this period, and the water collected below the outfall during this same period consisted entirely of ANL waste water. The average total alpha activity downstream from the waste water outfall was $11.8 \mu\mu\text{c}/1$, or about $8 \mu\mu\text{c}/1$ higher than found in upstream water, and this additional activity was evidently added to the Creek in ANL waste water. A similar difference was observed in 1955, while the corresponding differences in 1952, 1953, and 1954 were each about $25 \mu\mu\text{c}/1$. The uranium content of Sawmill Creek water indicated that most of the alpha activity added to the stream in Argonne waste water was due to natural uranium. In most of the below-outfall samples analyzed for both uranium and total alpha activity, the uranium content accounted for essentially all of the alpha activity. Above the outfall, the uranium concentration accounted for only about one half of the total alpha activity. The average uranium concentration below the outfall ($17.4 \mu\mu\text{c}/1$) was greater than the average total alpha activity ($11.8 \mu\mu\text{c}/1$) because most of the samples analyzed for uranium contained concentrations of alpha activity above average.

Some of the samples below outfall contained small but detectible concentrations of plutonium. The average plutonium concentration in the twelve samples in which it was detected was $7 \mu\mu\text{c}/1$, or about 0.5% of the maximum permissible concentration given in NBS Handbook 52. The highest plutonium concentration, $46 \mu\mu\text{c}/1$, was only 3% of the maximum permissible concentration. None of the samples obtained upstream from the waste water outfall contained plutonium concentrations in excess of the detection limit of $0.2 \mu\mu\text{c}/1$. Alpha activity due to thorium isotopes was essentially the same in water from both sampling locations, and therefore negligible amounts were derived from Laboratory waste water. The average concentration, $0.5 \mu\mu\text{c}/1$, was similar to that found in previous years.

The total alpha activity in water collected above the Laboratory site averaged $3.9 \mu\mu\text{c}/1$, and most of the individual samples contained between 1 and $5 \mu\mu\text{c}/1$. The uranium content varied between 0.5 and $3.5 \mu\mu\text{c}/1$ and averaged $2 \mu\mu\text{c}/1$. A few of the samples contained

TABLE VIII

NONVOLATILE ALPHA ACTIVITY IN SAWMILL CREEK WATER, 1956

Month	Location*	Total Alpha Activity			Uranium			Plutonium			Thorium					
		No. of Samples	$\mu\mu\text{c/liter}$		No. of Samples	$\mu\mu\text{c/liter}$		No. of Samples	Samples $>0.2 \mu\mu\text{c/l}$			No. of Samples	Samples $>0.2 \mu\mu\text{c/l}$			
			Max.	Av.		Max.	Av.		No.	Max.	Av.		No.	Max.	Av.	
Jan.	A	4	2.3	2.2	2	2.5	2.5	2	0	--	--	2	1	0.3	--	
Jan.	B	12	41.4	19.4	5	27.4	21.2	2	1	2.2	--	2	1	0.5	--	
Feb.	A	5	2.9	2.1	2	3.5	2.9	1	0	--	--	1	0	--	--	
Feb.	B	13	25.0	9.4	3	30.9	19.9	2	0	--	--	2	0	--	--	
March	A	4	2.7	2.2	2	2.8	2.0	1	0	--	--	1	0	--	--	
March	B	13	26.0	12.0	2	25.2	12.5	1	0	--	--	1	0	--	--	
April	A	4	4.0	3.1	2	2.8	2.6	2	0	--	--	2	1	0.3	--	
April	B	13	95.7	21.9	4	96.0	43.3	2	1	0.3	--	2	0	--	--	
May	A	4	3.0	2.7	2	2.0	1.6	0	-	--	--	0	-	--	--	
May	B	12	10.9	4.3	4	2.6	2.2	1	1	0.5	--	1	1	0.6	--	
June	A	4	8.5	4.3	3	2.6	2.3	2	0	--	--	2	2	0.6	0.4	
June	B	13	15.1	9.4	2	10.5	10.3	2	1	0.2	--	2	2	1.0	0.6	
July	A	3	12.1	8.7	2	1.4	1.0	2	0	--	--	2	0	--	--	
July	B	12	93.4	18.4	3	18.6	14.0	2	2	46	23	2	0	--	--	
August	A	4	9.4	5.1	2	0.9	0.8	2	0	--	--	2	1	1.2	--	
August	B	11	74.8	15.0	2	22.0	16.2	2	2	19.7	10.3	2	2	0.5	0.4	
Sept.	A	1	13.5	--	1	1.1	--	1	0	--	--	1	0	--	--	
Sept.	B	12	15.5	7.6	2	10.0	9.3	2	1	4.5	--	2	0	--	--	
Oct.	B	14	11.4	5.9	2	10.3	7.7	2	1	0.4	--	2	0	--	--	
Nov.	B	10	33.8	10.0	2	31.6	20.1	2	1	1.4	--	2	0	--	--	
Dec.	B	13	18.9	9.4	2	16.0	10.7	2	1	3.7	--	2	0	--	--	
Average	A		3.9			2.0				-				0.5		
	B		11.8			17.4				7				0.5		

*Location A is above the ANL waste water outfall.

Location B is below the ANL waste water outfall.

significantly higher concentrations of alpha activity, 8 to 13.5 $\mu\mu\text{c}/\text{l}$. The uranium concentrations in the latter samples were normal, and the additional alpha activity was due to other natural activities, notably radium.

Concentrations of beta activity in Sawmill Creek water are given in Table IX. Beta activity was added to the Creek as a result of fission product fallout and contamination in Laboratory waste water. Beta activity from these sources may be distinguished by comparing total beta activity and fission product activity in water from both sampling locations on the same day. On the basis of total activity measurements, fission product fallout was evident in the stream from February to September. During this period the average increase in total beta activity due to fallout was approximately 20 $\mu\mu\text{c}/\text{l}$. On several days during this period natural creek water, containing fallout activity, was diluted by Laboratory waste water containing little beta activity, with the result that the concentration of beta activity was greater above than below the outfall.

Beta activity added to the Creek in Laboratory waste water consisted of fission products and the UX_1 and UX_2 daughters of uranium. Contamination in Laboratory waste water was observed in most of the samples and usually contributed 5 to 25 $\mu\mu\text{c}/\text{l}$ of beta activity to below site Creek water, although three samples were found to contain more than 500 $\mu\mu\text{c}/\text{l}$ due to waste water. However, since the fractional contribution of fallout activity to the total beta activity is greater above than below site, the average increase in below site water was only 8 $\mu\mu\text{c}/\text{l}$.

Comparison of the fission product content of water from the two locations indicates a difference in age, and consequently a difference in source, of nuclides. The longer-lived fission products, Ce^{144} and Sr^{90} , were detected only in below-outfall water, while the shorter-lived fission products were more predominant in above-outfall water. None of the water samples analyzed for fission products contained biologically significant concentrations of the nuclides analyzed.

Sawmill Creek empties into the Des Plaines River about 500 yards downstream from the waste water outfall. By comparing the radioactivity in Des Plaines River water above and below the mouth of Sawmill Creek, the effect of the latter stream on the radioactive content of the River may be determined. The results, given in Table X, show that the average concentrations of alpha activity, beta activity, and uranium, were essentially the same at both sampling locations. Apparently due to dilution, the additional activity in Sawmill Creek water had no noticeable effect on the radioactivity in the Des Plaines River. The alpha activities and uranium concentrations were low, and very similar to that found in previous years. The beta activity is of course subject to fluctuations due to fission product fallout, and averaged about 15 $\mu\mu\text{c}/\text{l}$ higher this year than in 1954 and 1955.

TABLE IX
NONVOLATILE BETA RADIOACTIVITY IN SAWMILL CREEK, 1956

Month	Location*	Total Beta Activity			Sr ⁹⁰			Sr ⁸⁹			Ce ¹⁴⁴			Ce ¹⁴¹			I ¹³¹							
		No. of Samples	μc/liter		No. of Samples	Samples >3μc/liter		No. of Samples	Samples >3μc/liter		No. of Samples	Samples >3μc/liter		No. of Samples	Samples >3μc/liter		No. of Samples	Samples >3μc/liter						
			Max.	Av.		No.	Max.		Av.	No.		Max.	Av.		No.	Max.		Av.	No.	Max.	Av.			
January	A	4	8.6	6.3	2	0	-	-	2	0	-	-	2	0	-	-	2	0	-	-	0	-	-	-
January	B	12	36.0	24.8	2	0	-	-	2	0	-	-	2	0	-	-	2	0	-	-	0	-	-	-
February	A	5	53.0	31.1	2	0	-	-	2	1	8.9	-	2	0	-	-	2	1	10.6	-	0	-	-	-
February	B	13	193.5	35.0	2	0	-	-	3	2	16.0	10.7	2	1	6.7	-	2	0	-	-	1	0	-	-
March	A	4	53.4	20.3	2	0	-	-	2	1	6.9	-	2	0	-	-	2	0	-	-	1	0	-	-
March	B	13	30.4	19.7	2	0	-	-	2	0	-	-	2	0	-	-	2	0	-	-	1	0	-	-
April	A	4	17.3	9.3	2	0	-	-	2	1	6.0	-	2	0	-	-	2	0	-	-	2	0	-	-
April	B	13	88.1	27.7	2	0	-	-	2	1	5.0	-	2	0	-	-	2	0	-	-	2	2	4.4	3.9
May	A	4	37.0	20.9	2	0	-	-	2	2	11.5	8.6	2	0	-	-	2	0	-	-	2	1	5.4	-
May	B	12	545	66	2	0	-	-	2	2	6.6	5.3	2	1	9.5	-	2	0	-	-	2	0	-	-
June	A	4	20.0	14.9	2	0	-	-	2	1	3.6	-	2	0	-	-	2	0	-	-	2	0	-	-
June	B	13	23.6	15.1	2	0	-	-	2	0	-	-	2	0	-	-	2	0	-	-	2	0	-	-
July	A	3	72.1	52.5	2	0	-	-	2	2	14.7	12.6	2	0	-	-	2	0	-	-	2	2	11.7	9.0
July	B	12	746	102.	3	0	-	-	3	1	60	-	3	1	90	-	3	1	67	-	3	0	-	-
August	A	4	240	105	2	0	-	-	2	2	30.0	28.2	2	0	-	-	2	1	23.5	-	2	2	53.7	31.1
August	B	11	1285	157	2	1	38	-	2	2	145	76	2	1	122	-	2	1	5.8	-	2	0	-	-
September	A	1	180	-	1	0	-	-	1	1	52	-	2	0	-	-	2	1	18.3	-	0	-	-	-
September	B	12	56.5	25.2	2	0	-	-	2	1	10.4	-	2	0	-	-	2	1	9.3	-	2	1	4.5	-
October	B	14	56.8	28.1	2	1	3	-	2	1	7.9	-	2	0	-	-	2	0	-	-	2	0	-	-
November	B	10	23.4	16.1	2	0	-	-	2	0	-	-	2	0	-	-	2	1	4.4	-	2	0	-	-
December	B	13	51.5	25.0	2	0	-	-	2	0	-	-	2	0	-	-	2	0	-	-	2	0	-	-
Average	A		36				-			16				-			30					17		
	B		44				21			27.8				57			6.5					4		

*Location A is above the ANL waste water outfall.

Location B is below the ANL waste water outfall.

TABLE X
NONVOLATILE RADIOACTIVITY IN DES PLAINES RIVER, 1956

Date Collected	Location*	Alpha Activity ($\mu\mu\text{c/liter}$)	Uranium ($\mu\mu\text{c/liter}$)	Beta Activity ($\mu\mu\text{c/liter}$)
January 20	A	4.0	2.8	27.4
January 20	B	1.7	2.1	18.8
February 15	A	1.5	0.9	22.9
February 15	B	1.4	1.3	41.3
March 21	A	2.0	2.2	17.9
March 21	B	1.9	1.5	17.9
April 12	A	2.3	1.6	17.9
April 18	B	3.1	2.4	16.9
May 16	A	1.7	2.5	33.4
May 16	B	2.3	1.4	31.2
June 20	A	4.1	-	37.0
June 20	B	2.6	-	27.7
July 17	A	1.8	0.7	47.3
July 17	B	2.3	1.6	44.0
August 15	A	1.5	0.7	34.2
August 15	B	2.2	0.5	57.2
September 19	A	1.6	1.0	42.8
September 19	B	1.5	1.5	39.0
October 17	A	1.4	1.0	30.4
October 17	B	0.5	1.0	23.6
November 21	A	0.8	0.5	30.8
November 21	B	1.1	1.1	31.8
December	A	2.6	0.6	24.2
December	B	1.5	0.4	27.9
Average	A	2.1	1.3	30.5
	B	1.9	1.3	31.8

* Location A is approximately 5 miles above the mouth of Sawmill Creek.

Location B is approximately 2.5 miles below the mouth of Sawmill Creek.

2. Other Water

The total alpha and beta activity in the ponds on the ANL site are given in Table XI. Excluding the results for the storage lagoon, the alpha activities in these bodies of water were low, 1 to 3.5 $\mu\mu\text{c}/1$, and similar to the values found in previous years. The average total beta activity was 21 $\mu\mu\text{c}/1$, or about 9 $\mu\mu\text{c}/1$ higher than earlier values for these bodies, but the same as the average found in water within 25 miles of the Laboratory in 1956. The range of beta activities in the ponds, 11 to 33 $\mu\mu\text{c}/1$, was also the same as that found off the Laboratory site.

TABLE XI

NONVOLATILE RADIOACTIVITY IN PONDS ON ANL SITE, 1956

Date Collected	No. of Samples	Alpha Activity ($\mu\mu\text{c}/1$)		Beta Activity ($\mu\mu\text{c}/1$)	
		Max.	Av.	Max.	Av.
April 26	3	11.0 ¹	5.2	33.1 ¹	20.7
July 26	3	5.4 ¹	3.1	81.5 ¹	43.7
October 18	3	3.5	2.0	25.6	23.2
Average		3.4	2.1 ²	29.2	21.1 ²

¹ Storage lagoon for contaminated waste water.

² Average excluding results for storage lagoon in April and July.

Total alpha and beta activities in lakes and streams within 25 miles of the Laboratory are given in Tables XII and XIII. The average alpha activity, 1.8 $\mu\mu\text{c}/1$, was normal, and only two individual values exceeded 5 $\mu\mu\text{c}/1$. These latter values were obtained for the December samples from the Du Page River at Channahon (9.8 $\mu\mu\text{c}/1$) and Calumet Lake (5.4 $\mu\mu\text{c}/1$). The Du Page River has frequently contained higher concentrations of activity than the other bodies of water in the area, so the present value is not uncommon. The unusually high concentration of alpha activity in the Calumet Lake sample is associated with an abnormally high concentration of solid material (0.8 g/l) and is probably the result of a reduced amount of water in the lake at the time of sampling.

The average beta activity in surface water obtained within 25 miles of the Laboratory, 20 $\mu\mu\text{c}/\text{liter}$, was not significantly different from the averages of previous years. No important differences due to

TABLE XII

NONVOLATILE RADIOACTIVITY IN LAKES AND STREAMS NEAR ANL, 1956

Lake or Stream	Location	April		June		October		December	
		$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$
DesPlaines River ¹	Irving Park Road	1.9	15.8	1.7	14.0	0.9	23.9	1.3	21.4
DesPlaines River ¹	Willow Springs	2.3	17.9	4.1	37.0	1.4	30.4	2.6	24.2
DesPlaines River ²	Lemont	3.1	16.9	2.6	27.7	0.5	23.6	1.5	27.9
DesPlaines River ²	Romeoville	2.5	16.8	-	-	0.8	35.6	0.7	26.9
DuPage River	Naperville	4.6	11.2	-	-	1.4	15.1	2.5	23.5
DuPage River	Channahon	3.0	7.8	3.2	6.8	1.3	20.6	9.8	36.4
Fox River	Montgomery	1.0	10.7	-	-	0.5	11.7	-	-
Flag Creek	Willow Springs	1.0	13.3	-	-	0.1	25.4	1.4	19.8
Ill. and Mich. Canal	Channahon	1.3	11.6	0.8	9.6	0.2	11.2	0.7	39.0
Drainage Ditch	Andres	2.6	3.8	-	-	-	-	-	-
Saganaskee Slough	104th Ave. & Sag Canal	2.3	17.3	0.3	11.0	-	-	1.7	25.6
Calumet-Sag Canal	104th Ave. & Sag Canal	-	-	0.8	8.6	0.5	6.8	-	-
Long Run Creek	135th St. & Archer Ave.	-	-	2.0	8.7	-	-	0.8	8.0
Calumet Lake	111th St., Chicago	-	-	0.9	20.8	-	-	5.4	79.5
Lake Michigan	98th St., Chicago	-	-	0.2	2.7	-	-	0.2	3.4
Illinois River	Morris	-	-	1.8	20.5	-	-	2.1	9.9
McGinnis Slough	U.S. Rt. 45 & Ill. Rt. 7	-	-	-	-	0.4	23.7	-	-

¹Upstream from ANL site.

²Downstream from ANL site

TABLE XIII
NONVOLATILE RADIOACTIVITY IN
LAKES AND STREAMS NEAR ANL, 1956

Distance From ANL (miles)	Date	No. of Samples	Alpha Activity ($\mu\mu\text{C}/\text{l}$)		Beta Activity ($\mu\mu\text{C}/\text{l}$)	
			Max.	Av.	Max.	Av.
10	April	6	4.6	2.6	17.9	15.6
10	June	5	4.1	2.0	37.0	18.6
10	October	7	1.4	0.7	35.6	22.9
10	December	6	2.6	1.6	25.6	21.3
10	Average		1.7		20.8	
25	April	5	3.0	2.0	15.8	9.9
25	June	6	3.2	1.4	20.8	12.4
25	October	4	1.3	0.7	23.9	16.9
25	December	6	9.8	3.3	79.5	31.6
25	Average		2.0		18.1	
10 and 25	Average		1.8		19.5	

fallout or distance from the Laboratory were noted during the year. The beta activity in the sample obtained from Calumet Lake in December was unusually high, $80 \mu\mu\text{C}/\text{l}$, undoubtedly for the same reason given for the high alpha activity in this sample.

The alpha and beta activities in water from the reference sites (Table XIV) were normal and similar to those found in previous years. No unusual amount of fallout activity was noted in any of the samples. Since the Des Plaines River empties into the Illinois River, the latter stream is of particular interest. The Illinois River was sampled at Morris (Table XII), about 25 miles downstream from the Laboratory, and at two points about 80 miles downstream from the Laboratory (Table XIV). The activities at all three locations were very similar.

D. Bottom Silt

Total alpha and beta activities in bottom silt from Sawmill Creek and the Des Plaines River are given in Table XV. The total alpha and beta activities in bottom silt from Sawmill Creek above the Laboratory site were normal and averaged $25 \mu\mu\text{C}\alpha/\text{g}$ and $71 \mu\mu\text{C}\beta/\text{g}$. Bottom silt from the Creek below the ANL waste water outfall averaged $17 \mu\mu\text{C}\alpha/\text{g}$ and $14 \mu\mu\text{C}\beta/\text{g}$ higher than the samples above outfall; these increases are attributed primarily to an accumulation of uranium and fission products from Laboratory waste water. For those samples below the outfall that

TABLE XIV

NONVOLATILE RADIOACTIVITY IN WATER FROM REFERENCE SITES, 1956

Location	July		December	
	$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$
Lake Michigan, St. Joseph, Michigan	0.2	3.5	0.4	4.6
Magician Lake, Michigan	< 0.1	3.8	0.2	4.6
Shafer Lake, Indiana	1.4	8.6	0.9	7.2
Illinois River, Starved Rock State Park	2.8	23.6	-	-
Illinois River, Henry, Illinois	3.8	26.0	0.9	7.9
Lake Geneva, Wisconsin	0.4	3.8	0.2	6.7
Lake Delavan, Wisconsin	0.5	8.8	0.2	27.4
Average	1.3	11.2	0.5	9.7

TABLE XV

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT FROM
SAWMILL CREEK AND DES PLAINES RIVER, 1956

Date Collected	Sawmill Creek			Des Plaines River		
	Location ¹	$\mu\mu\alpha/g$	$\mu\mu\beta/g$	Location ²	$\mu\mu\alpha/g$	$\mu\mu\beta/g$
January 18	A	26	69	-	-	-
January 18	B	36	65	-	-	-
February 15	A	27	72	-	-	-
February 15	B	39	81	-	-	-
March 21	A	26	84	A	16	40
March 21	B	30	70	B	25	106
April 18	A	25	72	A	19	47
April 18	B	24	52	B	27	108
May 16	A	25	82	A	20	68
May 16	B	22	51	B	17	74
June 20	A	24	64	A	23	62
June 20	B	33	56	B	24	55
July 17	A	21	57	A	18	78
July 17	B	35	64	B	25	80
August 15	A	25	67	A	19	63
August 15	B	80	178	B	26	86
September 19	A	-	-	A	20	69
September 19	B	42	99	B	21	96
October 17	A	-	-	A	20	62
October 17	B	59	102	B	16	46
November 21	A	-	-	A	16	40
November 21	B	58	118	B	18	56
December 19	-	-	-	A	21	45
December 19	-	-	-	B	19	53
Average	A	25	71	A	19	57
	B	42	85	B	22	76

¹ Location A is above the ANL site. Location B is below the ANL waste water outfall.

² Location A is approximately 5 miles above the mouth of Sawmill Creek.
Location B is approximately 2.5 miles below the mouth of Sawmill Creek.

contained increased activity, the increases ranged from 25 to 50 $\mu\mu\text{c/g}$ for alpha activity and from 25 to 100 $\mu\mu\text{c/g}$ for beta activity. The beta activities in the latter samples decayed at a significantly lower rate than samples in which recent fallout activity was present. This is additional evidence that the increases were due to Laboratory waste water. Similar increases were found in previous years.

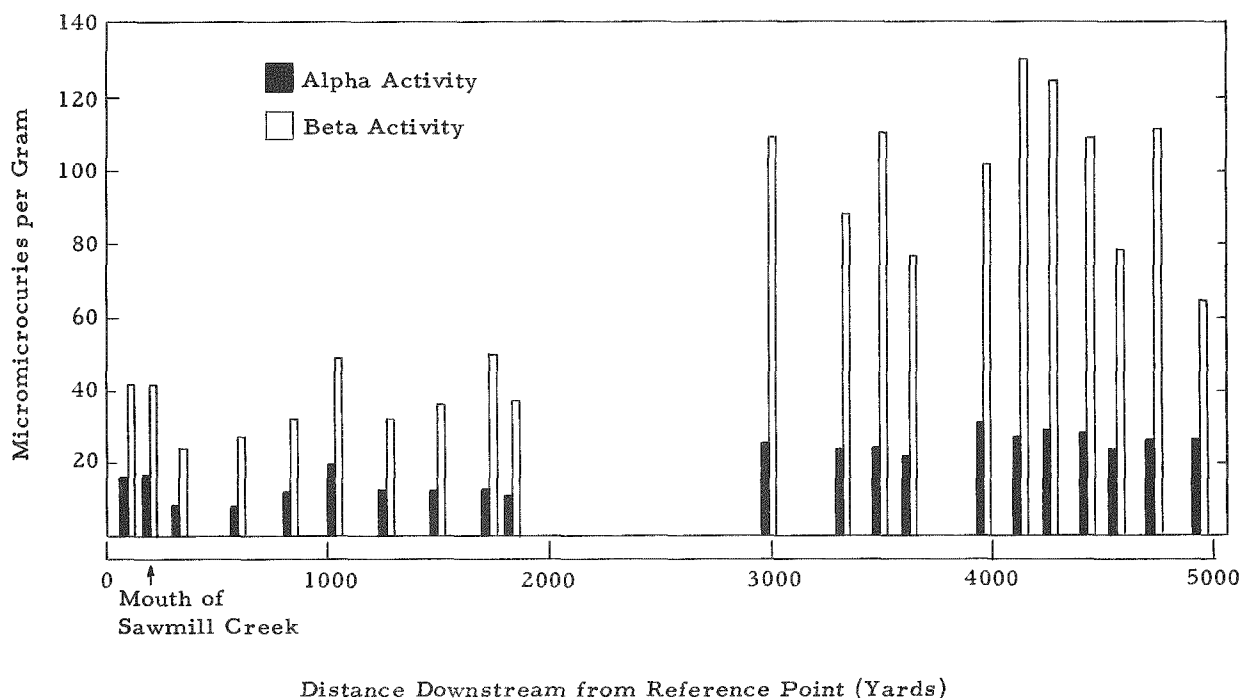
Comparison of the radioactivity in bottom silt from the Des Plaines River at both sampling locations showed no significant difference in alpha activity above and below Sawmill Creek. The average values, about 20 $\mu\mu\text{c/g}$, were normal and similar to those found during previous years. The average beta activity was 19 $\mu\mu\text{c/g}$ higher below Sawmill Creek. The samples collected in March, April, and September showed the greatest difference in beta activity between the two sampling locations, 25 to 65 $\mu\mu\text{c/g}$. Since these were months of relatively high fission product fallout, these differences in beta activity between the upstream and downstream locations were probably due to random variations in fallout accumulation that may occur in any stream bed. If the increased beta activities in bottom silt below the mouth of Sawmill Creek were due to contamination in Laboratory waste water, increases in alpha as well as beta activity, as was found in Sawmill Creek bottom silt, would be expected.

A survey of the bed of the Des Plaines River near ANL was made in October, 1956. The results are plotted in Figure 10 as a function of distance downstream from an arbitrary reference point. The alpha and beta activities near the mouth of Sawmill Creek were normal, so that there was no accumulation of activity from Laboratory waste water at this point. A notable feature of the plot is the significant difference between the activity in the first 2000 yards and the last 2000 yards sampled. The average activities in the former group of samples were 13 and 38 $\mu\mu\text{c/g}$ of alpha and beta activity, respectively. The corresponding values for the latter group of samples were 25 and 97 $\mu\mu\text{c/g}$. There was also no overlapping between the results from both groups. The reasons for this difference are not known at present. Additional analyses are planned to determine the source of the additional activity in the second group of samples.

It is possible that all of the additional alpha activity and some of the additional beta activity in the second group of samples were due to variations in the concentrations of naturally occurring radionuclides. In this respect, it is interesting to compare the sample at 3000 yards, collected on October 24, with the sample listed in Table XV for October 17. The samples were collected within 50 yards of each other. The sample collected on October 17 contained 16 $\mu\mu\text{c}\alpha/\text{g}$ and 46 $\mu\mu\text{c}\beta/\text{g}$, while the October 24 sample contained 25 $\mu\mu\text{c}\alpha/\text{g}$ and 110 $\mu\mu\text{c}\beta/\text{g}$. No large amount of activity was carried down in the rains between the two sampling dates. Surveys made of the Des Plaines River bed in previous years usually showed random variations in total activity with average results about midway between the two groups discussed above.

Figure 10

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT FROM
DES PLAINES RIVER, OCTOBER, 1956



The results obtained for bottom silt from the natural ponds on the ANL site are given in Table XVI. The alpha activities (an average of $27 \mu\mu\text{c/g}$ and a maximum value of $31 \mu\mu\text{c/g}$) were normal and similar to those obtained previously. The beta activities were normal in April and July, averaging about $70 \mu\mu\text{c/g}$. The average beta activity in the October samples was about twice the normal value. The rate of beta decay indicated the presence of fission product activity, probably the result of above normal amounts of fallout during September and October.

TABLE XVI

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT
FROM PONDS ON ANL SITE, 1956

Date Collected	No. of Samples	Alpha Activity ($\mu\mu\text{c/g}$)		Beta Activity ($\mu\mu\text{c/g}$)	
		Max.	Av.	Max.	Av.
April 26	2	31	29	73	70
July 26	2	25	25	73	73
October 18	2	29	28	205	158
Average		27		100	

The bed of the storage lagoon for contaminated waste water was sampled in September at a time when it was empty. The results are given in Table XVII as a function of depth. It is apparent that essentially all the adsorption of radionuclides from the water occurs in the upper two inches of the bed. In this upper layer the alpha activities were about ten times greater and the beta activities about forty times greater than normal bottom silt or soil. The samples from the upper two inches of the bed showed no decay in alpha or beta activity over a period of six months. Analysis of the top sample of boring number one showed the presence of significant concentrations of uranium, Sr⁹⁰, and Cs¹³⁷. Short-lived fission products were absent or present only in very low concentrations.

TABLE XVII

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT
FROM STORAGE LAGOON, SEPTEMBER, 1956

Depth	Boring No. 1 ¹		Boring No. 2 ²	
	$\mu\mu\alpha/g$	$\mu\mu\beta/g$	$\mu\mu\alpha/g$	$\mu\mu\beta/g$
0-2 in.	481	3260	356	2810
4 in.	-	-	27	65
1 ft.	40	96	40	77
2 ft.	32	80	29	75
3 ft.	33	61	35	66

¹Center of lagoon.

²Near outlet drain in lagoon.

The activity found in bottom silt from lakes and streams near ANL is given in Table XVIII and summarized in Table XIX. The average alpha and beta activities (23 and 54 $\mu\mu\alpha/g$ respectively) were normal and similar to those found in previous years. The range of the individual values was also normal, and no widespread increases due to fallout were observed.

The alpha and beta activities in bottom silt from the reference sites (Table XX) were uniformly low. The average values, 6 $\mu\mu\alpha/g$ and 27 $\mu\mu\beta/g$, were about 30% lower than in 1955.

E. Soil

The total activities found in soil on the ANL site are given in Table XXI. Except for the highest sample on October 25, the activities were normal, about 25 $\mu\mu\alpha/g$ and 50 to 70 $\mu\mu\beta/g$. The highly active sample, containing 62 $\mu\mu\alpha/g$ and 119 $\mu\mu\beta/g$, was collected near a uranium storage shed, and the increased alpha and beta activities were undoubtedly due to natural uranium and its daughters. This contamination is localized, however, and covers only the area immediately surrounding the shed.

TABLE XVIII

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT
FROM LAKES AND STREAMS NEAR ANL, 1956

Lake or Stream	Location	April		June		October		December	
		$\mu\mu\alpha/g$	$\mu\mu\beta/g$	$\mu\mu\alpha/g$	$\mu\mu\beta/g$	$\mu\mu\alpha/g$	$\mu\mu\beta/g$	$\mu\mu\alpha/g$	$\mu\mu\beta/g$
Des Plaines River ¹	Irving Park Road	18	47	21	74	16	27	16	56
Des Plaines River ¹	Willow Sptings	19	47	23	62	20	62	21	45
Des Plaines River ²	Lemont	27	108	24	55	16	46	19	53
Des Plaines River ²	Romeoville	24	140	--	--	5	12	16	29
DuPage River	Naperville	83	124	--	--	83	87	70	65
DuPage River	Channahon	32	61	31	85	20	33	26	50
Fox River	Montgomery	17	47	--	--	5	10	--	--
Flag Creek	Willow Springs	16	38	--	--	20	72	32	98
Ill. and Mich. Canal	Channahon	22	49	21	57	15	37	21	44
Drainage Ditch	Andres	13	36	--	--	--	--	--	--
Saganaskee Slough	104th Av. & Sag Canal	9	37	11	37	--	--	20	55
Long Run Creek	135th St. & Archer Ave.	--	--	25	54	--	--	27	65
Calumet Lake	111th St., Chicago	--	--	17	45	--	--	19	61
Lake Michigan	98th St., Chicago	--	--	8	36	--	--	3	29
Illinois River	Morris	--	--	3	18	--	--	8	22
McGinnis Slough	U.S. Rt. 45 & Ill. Rt. 7	--	--	--	--	23	85	--	--

¹Above mouth of Sawmill Creek.²Below mouth of Sawmill Creek.

TABLE XIX

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT FROM LAKES
AND STREAMS NEAR ANL, 1956

Distance From ANL (miles)	Month	No. of Samples	Alpha Activity ($\mu\mu\text{c}/\text{gram}$)		Beta Activity ($\mu\mu\text{c}/\text{gram}$)	
			Max.	Av.	Max.	Av.
10	April	6	83	30	140	82
10	June	4	25	21	62	52
10	October	6	83	28	87	61
10	December	7	70	29	98	59
10	Average		28		64	
25	April	5	32	20	61	48
25	June	6	31	17	85	53
25	October	4	20	14	33	27
25	December	6	26	16	61	44
25	Average		17		44	
10 and 25	Average		23		54	

TABLE XX

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT
FROM REFERENCE SITES, 1956

Location	July		December	
	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$
Lake Michigan, St. Joseph, Michigan	2.4	19	2.6	26
Magician Lake, Michigan	4.5	26	5.2	24
Shafer Lake, Indiana	3.2	24	5.6	33
Illinois River, Henry, Illinois	14.	43	11	30
Lake Geneva, Wisconsin	2.2	14	2.8	20
Lake Delavan, Wisconsin	7.4	27	7.3	30
Average	6	26	6	27

TABLE XXI
NONVOLATILE RADIOACTIVITY IN SOIL ON ANL SITE, 1956

Date Collected	No. of Samples	Alpha Activity ($\mu\mu\text{c}/\text{gram}$)		Beta Activity ($\mu\mu\text{c}/\text{gram}$)	
		Max.	Av.	Max.	Av.
April 26	4	29	23	63	57
July 26	4	26	21	71	60
October 18	4	22	19	64	58
October 25	5	62 ¹	32	119 ¹	81
Average		24		65	

¹Sample collected near uranium storage shed (see text).

The alpha and beta activities in surface soil off the Laboratory site are given in Tables XXII and XXIII. The results for each location were similar to those found during previous years. There was no significant difference in activity between samples collected on the ANL site and those obtained within 25 miles of the Laboratory. As was observed in other years, soil from the reference sites averaged 30 to 40% lower in both alpha and beta activity than soil from or near ANL. However, the natural radioactive content of the soil is primarily a function of the type of soil rather than of distance from ANL. The samples from the reference sites contain a larger proportion of sandy soils than samples obtained near or on the ANL site, and sandy soils contain less activity than soils consisting primarily of clay. There was no indication of recent fallout activity in the samples.

TABLE XXII
NONVOLATILE RADIOACTIVITY IN SURFACE SOIL NEAR ANL, 1956

Distance from ANL (miles)	Month	No. of Samples	Alpha Activity ($\mu\mu\text{c}/\text{gram}$)		Beta Activity ($\mu\mu\text{c}/\text{gram}$)	
			Max.	Av.	Max.	Av.
10	January	5	24	21	62	57
10	April	5	24	18	61	50
10	June	3	24	20	71	55
10	October	5	58	26	73	58
10	December	5	66	28	76	63
10	Average		23		57	
25	April	4	24	20	61	50
25	June	4	21	18	66	51
25	October	4	28	24	64	57
25	December	5	33	18	68	50
25	Average		20		52	
10 and 25	Average		22		55	

TABLE XXIII

NONVOLATILE RADIOACTIVITY IN SURFACE SOIL
FROM REFERENCE SITES, 1956

Location	July		December	
	$\mu\mu\alpha/g$	$\mu\mu\beta/g$	$\mu\mu\alpha/g$	$\mu\mu\beta/g$
St. Joseph, Michigan	5.5	20	3.9	15
Magician Lake, Michigan	17	49	13	49
Shafer Lake, Indiana	14	42	16	43
Starved Rock State Park, Ill.	9.3	13	-	-
Henry, Illinois	9.4	29	10	45
Geneva, Wisconsin	17	47	23	46
Delavan, Wisconsin	18	47	3.3	21
Average	13	35	12	36

The total activities in soil borings taken on the ANL site are listed in Table XXIV. These borings were taken in August, 1954 and analyzed in January, 1957. The results indicate that the natural alpha and beta activities remain quite constant to a depth of at least 35 feet. The alpha activities ranged from 17 to 26 $\mu\mu\alpha/g$ and the beta activities from 44 to 72 $\mu\mu\beta/g$.

TABLE XXIV

NONVOLATILE RADIOACTIVITY IN SOIL BORINGS
ON ANL SITE¹

Depth (ft)	Boring No. 1		Boring No. 2		Boring No. 3	
	$\mu\mu\alpha/g$	$\mu\mu\beta/g$	$\mu\mu\alpha/g$	$\mu\mu\beta/g$	$\mu\mu\alpha/g$	$\mu\mu\beta/g$
2.6	25	56	26	55	23	58
5.0	25	72	21	57	17	60
7.6	25	63	24	57	17	54
10.0	18	60	19	56		
12.6	22	59	17	57		
17.6	20	63	20	52		
20.0	20	57	21	57		
25.0	20	53	24	62		
27.0	19	57	-	-		
30.0	18	48	21	58		
35.0	20	44	22	53		

¹The samples were collected in August, 1954, and counted in January, 1957.

One of the steps in processing Laboratory waste water consists of filtration through sand. This sand was sampled in May 1956 and the results are given in Table XXV. Ten portions of sand were collected from various points in each bed and combined to give one sample for each sand bed. The total alpha and beta activities were about 50 and 15 $\mu\mu\text{c/g}$, respectively. No unused sand of this type was available for comparison, but on the basis of the activity found in Lake Michigan sand, about 90% of the alpha activity and 50% of the beta activity found in the sand from the filtration beds originated in the waste water. Ten-gram portions of the sand were leached with 6N HNO_3 and the solutions analyzed for uranium, alpha, and beta activity. The results are given under the columns headed "solution" in Table XXV. About 10% of the alpha activity was soluble in the acid, and most of the soluble alpha activity was due to uranium.

TABLE XXV
RADIOACTIVITY IN SAND FROM WATER FILTRATION BEDS

Bed No.	Sand		Solution		
	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$	$\mu\mu\alpha/\text{g}$	$\mu\mu\text{U}/\text{g}$	$\mu\mu\beta/\text{g}$
1	104	31	-	16.3	-
2	58	17	6.1	6.6	4.8
3	81	20	8.5	7.2	2.4
4	60	18	7.1	7.8	1.8
5	53	14	5.9	4.3	1.2
6	40	13	4.7	4.4	2.4
7	46	13	5.0	4.2	6.0
8	44	15	4.9	3.9	4.8

F. Plants

Collection of plants was limited to grass, since it was available at all sampling locations and permits intercomparison of results independent of type of plant.

The total activities in grass samples during 1956 are given in Tables XXVI, XXVII, and XXVIII. With two exceptions the alpha activities in grass from all locations were uniformly low and averaged about 1 $\mu\mu\text{c/g}$. The beta activities averaged 15 to 30 $\mu\mu\text{c/g}$ lower than samples from the same locations in 1955, indicating a reduced amount of fallout activity in grass samples this year. Although grass from the ANL site contained about 25 $\mu\mu\text{c/g}$ more beta activity than off-site grass this year, individual samples containing the same concentration of beta activity were obtained both on and off the Laboratory site. The beta activity in the higher samples

TABLE XXVI

NONVOLATILE RADIOACTIVITY IN GRASS ON ANL SITE, 1956

Date Collected	No. of Samples	Alpha Activity ($\mu\mu\text{c/g}$)		Beta Activity ($\mu\mu\text{c/g}$)	
		Max.	Av.	Max.	Av.
April 26	4	1.5	1.2	108	90
July 26	4	0.5	0.4	91	72
October 18	3	1.2	1.0	116	107
October 25	2	135 ¹	69	418 ¹	260
Average		18 1.0 ²		115 89 ²	

¹ Collected near uranium storage area. See Text.

² Average excluding storage area sample.

TABLE XXVII

NONVOLATILE RADIOACTIVITY IN GRASS NEAR ANL, 1956

Distance from ANL (miles)	Date	No. of Samples	Alpha Activity ($\mu\mu\text{c/g}$)		Beta Activity ($\mu\mu\text{c/g}$)	
			Max.	Av.	Max.	Av.
10	April	5	2.1	1.3	98	69
10	June	4	2.7	1.2	44	35
10	October	4	1.2	0.7	92	82
10	December	4	1.9	1.5	115	80
10	Average		1.4		67	
25	April	4	2.1	1.8	116	87
25	June	4	0.8	0.6	57	46
25	October	4	0.8	0.6	62	45
25	December	4	0.9	0.6	41	32
25	Average		0.9		52	
10 and 25	Average		1.2		60	

TABLE XXVIII

NONVOLATILE RADIOACTIVITY IN GRASS
FROM REFERENCE SITES, 1956

Location	July		December	
	$\mu\mu\text{ca/g}$	$\mu\mu\text{cb/g}$	$\mu\mu\text{ca/g}$	$\mu\mu\text{cb/g}$
St. Joseph, Michigan	0.7	44	--	--
Magician Lake, Michigan	--	--	0.7	52
Shafer Lake, Indiana	0.9	57	--	--
Starved Rock State Park, Ill.	0.9	60	1.0	88
Henry, Illinois	--	--	1.1	69
Geneva, Wisconsin	--	--	0.2	47
Delavan, Wisconsin	0.4	49	--	--
Average	0.7	53	0.8	64

from all locations decayed at the rate expected for fallout activity, and the differences in the average values are probably due to differences in the amount of fallout activity in the grass at the time of sampling. Except for two samples, activity due to Laboratory operations was not detected in grass samples. The two exceptions were a grass sample from the contaminated waste water lagoon and a sample collected near a uranium storage shed. The lagoon sample contained $42 \mu\mu\alpha/g$ and $561 \mu\mu\beta/g$, and most of this activity was of course derived from the contaminated water in the lagoon. Similar results were obtained in 1955. The grass collected near the uranium storage shed contained $135 \mu\mu\alpha/g$ and $418 \mu\mu\beta/g$. The abnormally high concentration of activity in soil from this location was mentioned previously. Since the grass sample was washed with water before the analysis, it is probable that the activity was incorporated in the plant structure. The contamination in the grass, however, was confined to the immediate area of the storage shed.

G. Animals

Only a limited number of animals were collected and analyzed. The value of the results obtainable from animal samples is not believed to justify an extensive sampling program similar to that undertaken for the other types of samples.

A sample of mixed fish collected in June, 1956 from the lagoons on the ANL site contained $0.2 \mu\mu\alpha/g$ of dried fish and $23 \mu\mu\beta/g$. In 1954, fish from the same lagoons contained $0.5 \mu\mu\alpha/g$ and $23 \mu\mu\beta/g$; in 1953, the corresponding values were 1.4 and 16. It is evident that there has been no accumulation of activity in the fish in these lagoons although these bodies of water drain a large part of the ANL site.

Field mice were collected from several areas on the Laboratory grounds. The total activities were similar in mice from all locations. Two specimens obtained near the waste water outfall contained 0.2 and $0.3 \mu\mu\alpha/g$ and 8.2 and $12.4 \mu\mu\beta/g$. Two specimens collected from an area of the grounds containing no installations or buildings contained 0.1 and $0.2 \mu\mu\alpha/g$ and 6.8 and $8.6 \mu\mu\beta/g$.