ARGONNE NATIONAL LABORATORY
P. O. Box 299
Lemont, Illinois

ENVIRONMENTAL RADIOACTIVITY AT
ARGONNE NATIONAL LABORATORY

Report for the Year 1955

Written by
J. Sedlet

Experimental Work Done By:

A. J. Barbera	C. M. Greene, Jr.
M. T. Epifani	F. S. Iwami
K. K. Gallagher	J. Sedlet
E. Wood	

Industrial Hygiene and Safety Division

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ENVIRONMENTAL RADIOACTIVITY AT ARGONNE NATIONAL LABORATORY

Report for the Year 1955

I. SUMMARY

The radioactive content of samples of rain, surface water, soil, plants, and material from the beds of surface waters (bottom silt) which were collected and analyzed in 1955 are given in this report. These samples were collected from the site of Argonne National Laboratory and from zones approximately 10, 25, and 100 miles from the Laboratory. The sampling locations are shown in Figures 4 and 5. 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. Some of the samples were also analyzed for specific elements and nuclides.

The average total activities in water, bottom silt, soil, and plants are summarized in Figure 1. Radioactive contamination resulting from ANL operations was found only in water from Sawmill Creek below the outfall of Laboratory waste water (below site), and in a few of the bottom silt samples from Sawmill Creek and the Des Plaines River below the Laboratory site. Beta activity from fission product fallout was also found in these and other samples.

Water from Sawmill Creek below site averaged $9.6 \mu\mu\text{c/liter}$, or about $7 \mu\mu\text{c/liter}$ higher than water from Sawmill Creek above the Laboratory site. This additional alpha activity was added to the stream in Laboratory waste and was due primarily to uranium. No significant concentrations of plutonium were found.

Small amounts of beta activity ($15\text{-}20 \mu\mu\text{c/liter}$) were added to Sawmill Creek in Laboratory waste water. However, since five to ten times as much beta activity entered the stream as fission product fallout from atomic detonations, the average beta activity, $39 \mu\mu\text{c/liter}$, was the same above and below the Laboratory site. Concentrations of Sr^{90} in downstream waters were low, averaging only $6.7 \mu\mu\text{c/liter}$ in the three samples in which it was detected. This was a significant decrease from 1954, when 12 samples contained an average of $24 \mu\mu\text{c Sr}^{90}\text{/liter}$.

No significant concentrations of alpha or beta activity attributable to ANL operations were found in Des Plaines River water. Evidently Sawmill Creek water was sufficiently diluted in the Des Plaines River so that the activity in ANL waste water had no detectable effect on the activity

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FIGURE 1.

AVERAGE RADIOACTIVITY IN
ENVIRONMENTAL SAMPLES, 1955.

in the Des Plaines River. The ponds on the ANL site contained normal amounts of radioactivity, 1.5 and 11.9 $\mu\mu\text{c/liter}$ of alpha and beta activity, respectively. Normal amounts of alpha activity (1-3 $\mu\mu\text{c/liter}$) were found in lakes and streams off the Laboratory site. A few off-site water samples contained about 10 $\mu\mu\text{c/liter}$ of beta activity due to fallout from recent atomic detonations; however, the average total beta activity, about 15 $\mu\mu\text{c/liter}$, was normal.

Normal concentrations of alpha and beta activity in bottom silt from Sawmill Creek are about 30 and 80 $\mu\mu\text{c/gram}$, respectively. Three of the samples obtained below site in 1955 averaged about twice the normal alpha activity and three times the normal beta activity. These increases are attributable to an accumulation of activity from Laboratory waste water. The additional alpha activity was due primarily to uranium, since about 25 $\mu\text{g U/gram}$ were found in bottom silt below the site, while the uranium concentration above the site was only 3 $\mu\text{g/gram}$ of bottom silt. The additional beta activity below site was due to uranium as well as to fission products of various ages. The fission product activity was probably derived from both Laboratory waste water and fallout from recent detonations. A similar situation with respect to beta activity was found in four bottom silt samples from the Des Plaines River downstream from the Laboratory site. No abnormal concentrations of alpha activity were found in bottom silt from the Des Plaines River.

A survey of the bed of Sawmill Creek below the waste water outfall showed no general accumulation of radioactivity from Laboratory waste water. Only one of the 18 samples collected contained abnormally high concentrations of radioactivity.

Concentrations of alpha activity in bottom silt from the natural ponds on the ANL site and from sampling locations away from the Laboratory were normal (10 to 25 $\mu\mu\text{c/gram}$). The beta activity in most of these samples was also normal (40 to 80 $\mu\mu\text{c/gram}$), although small increases, averaging 25 $\mu\mu\text{c/gram}$, due to fallout were noted in some of the samples.

Normal concentrations of alpha and beta activity were found in soil samples from all locations. The alpha activity in grass samples from all locations was normal, for those grass samples analyzed for uranium, the uranium accounted for 5-10% of the total alpha activity. Increases in the beta activity by factors of two to four were found in grass samples from all locations in April and June, and were due to fallout activity from recent detonations. Several samples were analyzed for Sr^{90} , and, except for one sample, the Sr^{90} concentrations ranged from 0.65 to 1.5 $\mu\mu\text{c/gram}$. One sample, obtained from a lagoon on the ANL site used to store contaminated water, contained 6.5 $\mu\mu\text{c Sr}^{90}\text{/gram}$. The additional Sr^{90} is, of course, derived from the water stored at intervals in the lagoon.

The average concentrations of radioactivity in water, bottom silt, surface soil, and plants for the years 1952-1955 are summarized in Figures 2 and 3. It is notable that the average alpha activity in Sawmill Creek, below site, which is due primarily to contamination in Laboratory waste water, has decreased by a factor of about three since 1953. The alpha activity in water from other locations remained relatively constant in this period. The beta activity in water samples, as well as in other types of samples, has fluctuated from year to year with changes in the amount of fission product fallout. The beta activity in plants increased by about a factor of two from 1953 to 1955, and during 1955 was about as large as in 1952. These changes were due to variations in the amount of fallout activity.

II. PROCEDURES

This report presents the results of analyses of environmental samples collected during 1955. The purposes of the environmental sampling program are to detect increases in the concentration of radioactivity on the ANL site and its environs, and to determine whether any such increases are the result of Laboratory operations. Samples were collected from the ANL site and from zones approximately 10, 25, and 100 miles from the Laboratory. The 100-mile sampling locations are referred to as reference sites. The sampling locations are shown in Figures 4 and 5. Since Laboratory waste water is discharged into Sawmill Creek, which in turn empties into the Des Plaines River, special emphasis was placed on sampling these streams. The number and types of samples collected are given in Table I.

Table I
SAMPLES COLLECTED IN 1955

Water	317	Rain	179
Surface Soil	94	Bottom Silt	146
Plants	86	Air	673
Animal	5		

Most of the samples were analyzed for total alpha and beta activities by direct counting following suitable preparation of the sample. The counting rates were converted to micromicrocuries ($\mu\mu\text{c}$) by applying corrections measured for Pu^{239} (for alpha particles) and Tl^{204} (for beta particles). Some of the samples were also analyzed for uranium, neptunium, plutonium, thorium, radium, potassium, and certain fission products. Uranium was

FIGURE 2.

AVERAGE RADIOACTIVITY IN WATER
AND BOTTOM SILT, 1952-1955.

FIGURE 3.

AVERAGE RADIOACTIVITY IN SURFACE
SOIL AND PLANTS, 1952-1955.

FIGURE 4
SAMPLING LOCATIONS ON SITE OF ARGONNE NATIONAL LABORATORY

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FIGURE 5
SAMPLING LOCATIONS NEAR ARGONNE NATIONAL LABORATORY

determined fluorometrically. The other elements and nuclides were determined by counting after suitable chemical separations. The activities found in air samples will be given in a separate report.

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, and ANL-5446.

III. RADIOACTIVITY IN ENVIRONMENTAL SAMPLES

A. Rain

The total alpha and beta activities in precipitation collected at ANL are summarized in Table II. The beta activity remaining one week after the end of the rainfall was largely due to fission products.

Table II

NONVOLATILE RADIOACTIVITY IN RAINWATER AT ANL, 1955

Month	No. of Samples ¹	Alpha Activity ($\mu\mu\text{c/liter}$)				Beta Activity ($10^2\mu\mu\text{c/liter}$)			
		After 1 day of decay		After 1 week of decay		After 1 day of decay		After 1 week of decay	
		Max.	Av.	Max.	Av.	Max.	Av.	Max.	Av.
January	9	42	13	8.0	5.0	3.0	1.5	2.7	1.2
February	9	61	12	15.0	5.0	127	18	49.6	8.8
March	14	64	16	8.5	2.2	1080	224	304	73
April	14	40	12	10.7	2.9	76.4	22.1	47.3	12.7
May	14	48	13	8.7	3.0	510	132	250	72
June	12	53	9	10.8	1.8	148	25	100	19
July	9	55	14	12.0	3.3	19.6	4.8	17.3	3.5
August	6	50	15	4.6	2.0	3.6	1.6	2.9	1.0
September	9	77	23	9.6	2.9	3.1	1.4	2.8	1.2
October	12	48	11	6.7	2.2	1.9	0.6	1.8	0.6
November	11	44	22	21.0	3.9	21.4	5.0	15.0	3.3
December	4	44	13	35	10	14.8	5.4	12.6	4.5

¹Two successive portions were collected for heavy rains and were considered as separate samples. Each portion was equivalent to 0.1 inch of rain.

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From about the middle of February to the middle of July the relatively large concentration of beta activity in the samples was due to fission products from atomic detonations occurring about 1 to 8 weeks prior to the rainfall. This was evident from the rate of decay of the total beta activity and the relative concentrations of barium, strontium, cerium, and iodine. The presence of fission products of recent origin was also noted in other types of samples. Similar increases were also found in a few of the samples collected in November and December, and these are also considered to be the result of fallout from recent detonations. At other times during the year, the decay rate indicated that the beta activity consisted primarily of fission products with half lives greater than about 50 days. The average long-lived beta activity in rain during 1955 was two to three times greater than in 1953 and 1954, but considerably less than in 1952.

On March 3 hail and rainwater fell simultaneously, and samples of each were analyzed separately. The rainwater contained about ten times as much beta activity as the hail stones. The long-lived alpha activity was about the same in both types of samples; however, much of this activity was probably derived from surface dust.

In order to determine the distribution of the radioactive nuclides in a given rainfall, several rain samples were collected in 0.025-inch portions, and each portion was counted separately for alpha and beta activity. The distribution of radioactivity in the various portions is given in Table III. In general the radioactivity was distributed among the various portions in about the same proportions as the solid material, and most of the solids and activity were carried down early in the rain. The only significant deviation from this generalization occurred in the sample dated November 22.

B. Surface Water

1. Sawmill Creek and Des Plaines River

ANL waste water is discharged in Sawmill Creek (Figure 4). By comparing the radioactive content of water from the Creek upstream and downstream from the waste water outfall, the amount of radioactivity contributed to this stream by ANL waste water can be determined. Monthly summaries of alpha activity in water from the two sampling locations are given in Table IV. The alpha activity in water obtained below the waste water outfall averaged approximately $7 \mu\mu\text{c/liter}$ higher than in water taken upstream from the ANL site, and this additional alpha activity was evidently added to the stream in ANL waste water. This is a reduction from 1954, when the corresponding difference was about $20 \mu\mu\text{c/liter}$. The uranium content of the water indicated that the alpha activity contributed by ANL waste water was essentially due to normal uranium. The sum of the alpha activities due to thorium and plutonium isotopes was uniformly low throughout the year and averaged essentially the same in water from both locations. Since only negligible amounts of plutonium are expected in water upstream

Table III

DISTRIBUTION OF RADIOACTIVITY IN RAINWATER, 1955

Date of Rain	Amount (inches)	Portion	% Solid Residue	% Alpha Activity	% Beta Activity
April 4	0.07	1	38	48	38
		2	42	33	35
		3	20	19	27
April 11	0.35	1	53	61	45
		2	16	18	18
		3	10	7.5	12
		4	11	7.5	9.5
		5	6	4	9.5
		6	4	2	6
April 18	0.26	1	35	45	52
		2	23	22	16
		3	21	15	11
		4	10	6	11
		5	7	5	6
		6	4	7	4
April 19	0.26	1	50	47	33
		2	21	27	32
		3	10	12	15
		4	7	9	9
		5	7	3	7
		6	5	2	4
May 22	1.05	1	44	35	33
		2	18	14	15
		3	16	20	14.5
		4	8	10	10
		5	8	14	11.5
		6	6	7	16
June 6	0.60	1	47	49	35
		2	31	33	32
		3	9	8	13
		4	6	4.5	9
		5	4	3	6
		6	3	2.5	5
July 5	0.24	1	27	28	25
		2	25	26	30
		3	21	18	21
		4	15	16	14
		5	8	8	7
		6	4	4	3
October 23	0.06	1	55	67	48
		2	29	26	36
		3	12	4	11.5
		4	4	3	4.5
November 22	0.22	1	45	41	24
		2	20	19	13
		3	13	13	10
		4	8	6	7
		5	10	18	37
		6	4	3	9

from the ANL site, the thorium plus plutonium activities found in water downstream from the ANL outfall must also be due primarily to thorium, and the average plutonium content of ANL waste water was negligible. The only significant indication of plutonium in ANL waste water was found in June, when the downstream water in two samples averaged $0.9 \mu\mu\text{c/liter}$ of thorium plus plutonium activity, while upstream water collected on the same days contained $0.1 \mu\mu\text{c/liter}$ of thorium and plutonium.

Table IV

NONVOLATILE ALPHA ACTIVITY IN SAWMILL CREEK WATER, 1955

Month	Location ¹	Total Alpha Activity			Uranium			Th + Pu		
		No. of Samples	$\mu\mu\text{c/liter}$		No. of Samples	$\mu\mu\text{c/liter}$		No. of Samples	$\mu\mu\text{c/liter}$	
			Max.	Av.		Max.	Av.		Max.	Av.
January	A	4	4.4	2.3	2	1.2	1.2	2	1.4	0.8
	B	12	18.7	9.8	4	7.3	6.3	2	0.2	0.2
February	A	4	2.3	2.0	2	1.8	1.5	2	0.1	0.1
	B	12	20.5	9.6	6	21.3	12.1	2	0.6	0.4
March	A	5	2.8	2.2	2	1.6	1.5	2	0.3	0.2
	B	13	17.3	6.9	4	12.8	6.7	2	0.3	0.2
April	A	3	1.9	1.8	2	1.4	1.3	1	0.3	-
	B	12	20.7	10.5	4	24.5	18.3	2	0.4	0.3
May	A	3	2.7	2.1	3	1.9	1.5	2	0.1	0.1
	B	11	21.2	11.7	6	13.4	8.7	2	0.5	0.3
June	A	3	2.5	2.1	3	1.2	0.9	2	0.1	0.1
	B	13	17.0	8.1	5	16.1	5.2	2	1.6	0.9
July	A	3	3.4	2.7	2	1.3	1.1	2	1.3	0.8
	B	12	10.4	7.1	6	9.1	6.2	3	0.3	0.2
August	A	4	3.8	3.4	2	3.2	3.2	2	0.3	0.3
	B	13	12.7	7.5	8	13.0	8.0	2	0.2	0.2
September	A	2	3.0	2.2	2	2.1	1.9	1	0.1	-
	B	11	10.1	7.9	6	11.5	7.1	2	0.4	0.3
October	A	3	3.5	2.4	2	1.5	1.1	2	1.4	0.8
	B	11	13.5	7.0	5	11.8	8.7	1	0.1	-
November	A	3	2.6	2.3	2	3.0	2.2	1	0.5	-
	B	12	26.4	11.7	9	24.0	12.2	2	0.4	0.3
December	A	4	2.4	2.3	2	2.5	2.2	-	-	-
	B	11	50.8	18.7	9	50.2	21.8	-	-	-
Average	A		2.3			1.6			0.4	
	B		9.6			10.7			0.3	

¹Location A is upstream from the ANL site.

Location B is downstream from the ANL waste water outfall.

Concentrations of beta activity found in Sawmill Creek water are summarized in Table V. Although some beta activity was added to the stream in ANL waste water, considerably larger amounts were added from fission product fallout, with the result that the average total beta activity ($39 \mu\mu\text{c/liter}$) was the same in water from both locations. The beta activity added in ANL waste water can be distinguished from fallout activity by comparing the total beta activity in upstream and downstream water collected on the same day during periods of little fallout, and by comparing the concentrations of long-lived fission products (e.g., Sr^{90} and Ce^{144}) during periods of high fallout. From March to June most of the added beta activity in the Creek was due to fallout from recent atomic detonations, although a few samples contained contaminated waste water. During the remainder of the year, Laboratory waste water provided the principal source of radioactive contamination in the Creek. The beta activity added in Laboratory waste water averaged 15 to $20 \mu\mu\text{c/liter}$. Fallout contamination was five to ten times higher.

Concentrations of Sr^{90} in downstream water were low, averaging only $6.7 \mu\mu\text{c/liter}$ in the three samples in which it was detected. This was a significant decrease from 1954, when 12 samples contained an average of $24 \mu\mu\text{c Sr}^{90}/\text{liter}$.

On April 20, 118,000 gallons of waste water containing $960 \mu\mu\text{c/liter}$ of total beta activity and $27.9 \mu\mu\text{c/liter}$ of Sr^{90} were discharged into Sawmill Creek from a water storage lagoon. Creek water collected prior to the discharge of this waste water contained about $160 \mu\mu\text{c/liter}$ of beta activity, primarily due to fallout from an 0.8-inch rainfall on that day. The Creek was sampled again while the waste water was being discharged, and while the fallout activity was still high, the Sr^{90} content in below site water was $5.0 \mu\mu\text{c/liter}$; this indicates a dilution factor of about five in the Creek. Most of this dilution was due to the heavy rainfall; normal dilution factors for the stream are considerably lower. The Sr^{90} found in the Creek was contributed by the waste water, since the Sr^{90} content of upstream water on that day was very low.

Sawmill Creek empties into the Des Plaines River about 500 yards downstream from the waste water outfall, and water from the Des Plaines River was sampled above and below the mouth of Sawmill Creek to measure the effect of the latter stream on the radioactive content of the Des Plaines River. The results, given in Table VI, indicate that Sawmill Creek water was sufficiently diluted so that the radioactivity in the ANL waste water had no detectable effect on the activity in the Des Plaines River. The total alpha activity, uranium concentration, and total beta activity (Table VI), except for the downstream sample in March, were essentially the same both above and below the mouth of Sawmill Creek. The high beta activity in the downstream sample in March was due to fresh fallout activity from a nuclear detonation. This was indicated by the rate of decay of the beta activity, and the large concentration of short-lived fission

Table V

NONVOLATILE BETA ACTIVITY IN SAWMILL CREEK WATER, 1955

Month	Location ¹	Total Beta Activity			Sr ⁹⁰			Ba ¹⁴⁰			Ce ¹⁴⁴			Ce ¹⁴¹			
		No. of Samples	μuc/liter		No. of Samples	Samples >3 μuc/liter		No. of Samples	Samples >3 μuc/liter		No. of Samples	Samples >3 μuc/liter		No. of Samples	Samples >3 μuc/liter		
			Max.	Av.		No.	μuc/liter		No.	μuc/liter		No.	μuc/liter				
							Max.			Av.			Max.		Av.	Max.	Av.
January	A	4	22.8	9.3	2	0	-	-	2	0	-	0	-	2	0	-	
	B	12	21.9	14.6	2	0	-	-	2	0	-	0	-	2	0	-	
February	A	4	7.6	5.7	2	0	-	-	2	0	-	0	-	2	0	-	
	B	12	166	49	4	0	-	5.6	4	0	-	0	-	4	1	6.9	
March	A	5	415	135	2	1	7.4	-	2	0	-	0	-	2	0	-	
	B	13	250	51	2	1	4.2	-	2	0	-	0	-	2	0	-	
April	A	3	16.9	10.0	2	0	-	-	2	0	-	0	-	2	0	-	
	B	12	168	31.8	2	0	-	5.0	2	0	-	0	-	2	0	-	
May	A	3	494	143	2	0	-	-	2	0	-	0	-	2	0	-	
	B	11	610	143	2	1	47	-	2	0	-	1	194	2	0	-	
June	A	4	110	59	2	2	13	12	2	0	-	0	-	2	0	-	
	B	13	96	49	2	2	22	14	2	0	-	0	-	2	0	-	
July	A	3	18.7	14.9	2	2	9.1	7.8	2	0	-	0	-	2	0	-	
	B	12	20.6	14.8	2	1	6.5	-	2	0	-	0	-	2	0	-	
August	A	4	13.3	11.6	2	0	-	-	2	0	-	0	-	2	0	-	
	B	13	23.1	17.7	2	0	-	-	2	0	-	0	-	2	0	-	
September	A	2	13.0	11.0	2	0	-	-	2	0	-	0	-	2	0	-	
	B	11	53.4	26.9	2	0	-	-	2	0	-	0	-	2	0	-	
October	A	3	18.3	11.6	3	0	-	-	3	0	-	0	-	3	0	-	
	B	11	232	35.8	3	0	-	-	3	0	-	1	11	3	0	13.4	
November	A	3	9.6	7.6	2	0	-	-	2	0	-	0	-	2	0	-	
	B	12	86.2	22.0	2	0	-	-	2	0	-	0	-	2	0	-	
December	A	4	6.9	5.3	2	0	-	-	2	0	-	0	-	2	0	-	
	B	11	39.8	22.8	2	0	-	-	2	0	-	0	-	2	0	-	
Average	A		39			0		6.7									
	B		39			20										11.2	

¹Location A is upstream from the ANL site.

Location B is downstream from the ANL waste water outfall.

products in a rainfall on the same day. The uranium and total alpha activities in Des Plaines River water were essentially the same as those found in previous years. The average total beta activities have shown considerable variation, from about 500 $\mu\mu\text{c/liter}$ in 1952 to 14 $\mu\mu\text{c/liter}$ in 1954, due to variations in the amount of fission product fallout.

Table VI

NONVOLATILE RADIOACTIVITY IN DES PLAINES RIVER, 1955

Date	Location ¹	Alpha Activity ($\mu\mu\text{c/liter}$)	Uranium ($\mu\mu\text{c/liter}$)	Beta Activity ($\mu\mu\text{c/liter}$)
January 19	B	3.1	2.4	7.2
February 16	B	3.8	2.9	11.3
March 30	A	2.4	-	9.9
March 16	B	2.1	1.8	500
April 20	B	2.7	1.8	10.2
May 18	A	-	2.4	33.2
May 18	B	3.2	2.1	28.6
June 15	A	2.3	1.3	32.4
June 15	B	2.1	1.1	8.9
July 20	A	4.8	1.4	16.7
July 20	B	2.8	1.3	14.5
August 17	A	2.7	0.8	13.1
August 17	B	1.8	0.7	15.3
September 19	A	1.8	0.7	16.1
September 19	B	2.2	0.8	13.7
October 19	A	2.0	1.3	13.0
October 19	B	4.3	1.1	23.8
November 9	A	2.3	1.2	16.3
November 9	B	1.9	0.5	16.0
December 21	A	2.3	-	15.4
December 21	B	2.9	2.2	15.7
Average	A	2.6	1.3	18.5
	B	2.7	1.6	{ 55 15.0 ²

¹Location A is upstream from the mouth of Sawmill Creek.
Location B is downstream from the mouth of Sawmill Creek.

²Average beta activity excluding the March sample from location B (see text).

2. Other Water

The radioactivities found in water from the natural ponds on the ANL site are given in Table VII. The total alpha and beta activities and uranium concentrations were normal and similar to those found in these ponds during previous years. Two of the samples from the lagoon used to store contaminated waste water contained abnormally high concentrations of alpha and beta activity. A sample obtained in April contained 18 and 960 $\mu\mu\text{c/liter}$ of alpha and beta activities, respectively; the corresponding values for a December sample were 68 and 246. In both cases most of the alpha activity was due to uranium and the beta activity primarily to fission products. The December sample also contained about 10 $\mu\mu\text{c Ra}^{266}\text{/liter}$.

Table VII

NONVOLATILE RADIOACTIVITY IN PONDS ON ANL SITE, 1955

Month	Alpha Activity			Beta Activity			Uranium	
	No. of Samples	$\mu\mu\text{c/liter}$		No. of Samples	$\mu\mu\text{c/liter}$		No. of Samples	$\mu\mu\text{c/liter}$
		Max.	Av.		Max.	Av.		
April	4	1.5	1.3	4	8.6	7.6	1	1.3
May	2	5.0	3.4	2	14.4	10.7	1	2.8
June	3	1.0	0.7	3	29.6	22.7	-	-
October	2	1.4	1.4	2	8.9	8.8	1	0.9
December	1	1.1	-	1	4.9	-	1	1.1
Average		1.5			11.9			1.5

The total alpha and beta activities in water from lakes and streams within 25 miles of the ANL site are listed in Table VIII and summarized in Table IX. The alpha activity averaged 2 $\mu\mu\text{c/liter}$ and was similar to that found previously at these locations and to the alpha activity in Sawmill Creek above the Laboratory site in 1955. The individual results were usually low; only one sample contained more than 5 $\mu\mu\text{c/liter}$. The beta activities, averaging 19 $\mu\mu\text{c/liter}$, were also similar to those found in previous years. The high beta activity (500 $\mu\mu\text{c/liter}$) mentioned previously for the sample from the Des Plaines River in March is reflected in the high average value for the March samples. However, except for this sample, the beta activity was relatively low, since the samples were collected during periods of relatively little fallout.

Table VIII

NONVOLATILE RADIOACTIVITY IN WATER FROM LAKES AND
STREAMS NEAR ANL, 1955

Lake or Stream	Location	March		June		October		December	
		$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$
Des Plaines River	Irving Park Road	1.8	6.9	2.9	11.1	-	-	3.9	8.1
Des Plaines River	Willow Springs Bridge	2.4	9.9	2.3	32.4	2.0	13.0	2.3	15.4
Des Plaines River	Lemont Road Bridge	2.1	500	2.1	8.9	4.3	23.8	2.9	15.7
Des Plaines River	Romeoville	2.1	8.4	2.5	18.3	1.2	9.3	3.2	12.7
Du Page River	Naperville	2.3	5.6	2.9	10.1	1.6	9.9	2.8	14.2
Du Page River	Channahon	1.7	4.0	2.3	5.8	2.7	7.0	1.2	8.8
Du Page River	Lisle	3.1	5.5	1.8	10.6	-	-	-	-
Du Page River East Branch	Glen Ellyn	3.3	4.1	2.3	6.9	2.0	5.7	4.1	4.4
Fox River	Montgomery	0.6	9.2	2.2	9.2	0.6	5.7	2.2	6.5
Lake Michigan	98th St., Chicago	0.3	2.8	0.2	2.6	0.6	6.4	0.4	5.0
Calumet Lake	111th St., Chicago	2.0	20.5	0.6	29.2	0.9	16.8	-	-
Saganaskee Slough	104th Ave. and Sag Canal	0.5	12.5	0.3	28.5	0.5	8.6	1.9	11.2
Ill. & Mich. Canal	Channahon	0.8	6.4	0.9	13.1	2.9	11.9	1.4	8.8
Flag Creek	Willow Springs	2.8	8.9	1.9	13.5	8.6	17.5	1.0	20.0
Long Run Creek	Ill. Rt. 4A & 135th St.	1.2	8.6	1.8	6.2	0.9	7.3	2.3	6.0
Drainage Ditch	Andres	1.4	3.4	2.2	6.0	-	-	-	-

Table IX

NONVOLATILE RADIOACTIVITY IN WATER FROM LAKES
AND STREAMS NEAR ANL, 1955

Distance from ANL (miles)	Month	No. of Samples	$\mu\mu\alpha/\text{liter}$		$\mu\mu\beta/\text{liter}$	
			Max.	Av.	Max.	Av.
10	March	8	3.1	2.1	500	70
10	June	8	2.9	2.0	32.4	16.1
10	October	7	8.6	2.7	23.8	12.8
10	December	7	3.2	2.3	15.7	13.6
25	March	8	3.3	1.5	20.5	7.2
25	June	8	2.9	1.7	29.2	10.5
25	October	6	2.9	1.6	16.8	8.9
25	December	6	4.1	2.2	20.0	7.0
Average			2.0		19	

The alpha activities in water from the sampling locations 100 miles from the Laboratory (Table X) were normal and similar to those found in previous years. Small increases in beta activity, about $10\mu\mu\text{c/liter}$, were noted in a few of these samples collected in March, and are attributed to fallout. The average beta activity, however, was similar to that found in 1953 and 1954.

Table X

NONVOLATILE RADIOACTIVITY IN WATER FROM
REFERENCE SITES, 1955

Location	June			December		
	$\mu\mu\text{c}\alpha/1$	$\mu\mu\text{c}\beta/1$	$\mu\mu\text{cU}/1$	$\mu\mu\text{c}\alpha/1$	$\mu\mu\text{c}\beta/1$	$\mu\mu\text{cU}/1$
Magician Lake, Michigan	0.2	13.8	0.2	0.2	1.8	0.2
Lake Michigan, St. Joseph, Mich.	0.3	8.3	-	0.4	6.8	-
Shafer Lake, Indiana	0.9	18.5	1.2	1.8	3.8	0.9
Iroquois River, Iroquois, Ill	1.8	17.1	1.2	-	-	-
Illinois River, Starved Rock State Park	2.7	26.5	1.0	1.7	9.1	-
Illinois River, Henry, Illinois	3.4	13.2	-	1.7	8.4	-
Lake Geneva, Wisconsin	0.3	3.1	-	0.4	2.6	-
Lake Delavan, Wisconsin	1.1	8.4	0.6	0.6	7.6	0.5
Average	1.3	13.6	0.8	1.0	5.7	0.5

C. Bottom Silt

The total alpha and beta activities found in bottom silt from the Laboratory site are given in Table XI. Samples obtained below the waste water outfall in May, September, and October contained 25 to $50\mu\mu\text{c/gram}$ more than the normal alpha activity, and this increase is attributed primarily to uranium contamination in Laboratory waste water. The May and September samples obtained below the outfall contained, respectively, 21 and 28 micrograms of uranium per gram of silt, while the corresponding values for the above site samples were 3 and 2.8. The uranium concentrations in the above site samples may be considered normal, since seven bottom silt samples from the 10 and 25-mile sampling zones contained from 1.5 to $3.2\mu\text{g U/gram}$.

Table XI

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT FROM ANL SITE, 1955

Date Collected	Sawmill Creek				Ponds on ANL Site				
	Above ANL Site		Below ANL Water Outfall		No. of Samples	$\mu\mu\alpha/\text{gram}$		$\mu\mu\beta/\text{gram}$	
	$\mu\mu\alpha/\text{gram}$	$\mu\mu\beta/\text{gram}$	$\mu\mu\alpha/\text{gram}$	$\mu\mu\beta/\text{gram}$		Max.	Av.	Max.	Av.
January 19	24	69	15	31	-	-	-	-	-
February 16	25	57	23	56	-	-	-	-	-
March 16	18	54	28	67	-	-	-	-	-
April 20	24	77	28	68	5	29	27	80	68
May 18	27	73	53	108	-	-	-	-	-
June 15	29	198	20	50	3	29	21	77	70
July 20	26	79	29	77	-	-	-	-	-
August 17	22	72	38	114	-	-	-	-	-
September 21	26	86	60	133	-	-	-	-	-
October 25	24	80	18 ¹	61 ¹	3	147 ²	67	373 ²	173
November 9	31	79	35	82	-	-	-	-	-
December 21	30	55	39	88	3	96 ²	51	360 ²	167
Average	26	82	24	68		39 26 ³		112 70 ³	

¹Average of 18 samples. Maximum values in this group were 75 $\mu\mu\alpha/\text{gram}$ and 375 $\mu\mu\beta/\text{gram}$.

²Storage lagoon for contaminated water.

³Average excluding samples from storage lagoon.

The average beta activity in bottom silt obtained from Sawmill Creek at both sampling locations was about 75 $\mu\mu\beta/\text{gram}$. Although this value is approximately normal for this stream, individual samples showed significant increases above the normal value. The sample collected above site in June contained 198 $\mu\mu\beta/\text{gram}$, or about three times greater than normal. Since the alpha activity in this sample remained normal, and since the beta activity decayed at an above normal rate, this increase was probably due to an accumulation of fresh fission product fallout. This sample decayed a total of 50% in six months as contrasted with a decay rate of 15 to 25% in most bottom silt samples.

Samples collected below site in May, August, September, and the highest sample in October, contained from 25 to 400% more beta activity than normally observed. The rate of beta decay in these samples indicated that the additional beta activity was a mixture of fresh and aged fission products, and was probably derived from both fallout and Laboratory waste water. The samples collected in May and September from Sawmill Creek above and below the waste water outfall were analyzed for Sr^{90} and Ce^{144} , and all four samples contained less than 2 $\mu\mu\text{c}$ of the nuclides per gram of bottom silt.

A survey of the bed of Sawmill Creek below the waste water outfall was made in October to determine the effect of the activity in Laboratory waste water on the radioactive content of the bed of the stream. The results are plotted in Figure 6 as a function of distance downstream from the water outfall. Only one sample, collected 35 yards downstream from the outfall, showed a significant increase in activity which could be attributed, in part, to ANL operations. This sample, which contained 75 and 375 $\mu\mu\text{c}$ /gram of alpha and beta activities, respectively, has been discussed previously. All other samples obtained during this survey contained normal concentrations of radioactivity, and no evidence was obtained which indicated general contamination of the bed of the Creek. The results of this survey confirm the following observations made in previous years regarding bottom silt samples: the radioactive nuclides absorbed on the silt, or the silt itself, are apparently subject to considerable movement, since the radioactive content of bottom silt from a given stream may vary widely with location and with time at the same location.

The radioactivities in bottom silt from the natural ponds and the storage lagoon on the ANL site are given in Table XI. The activities in bottom silt from the ponds, about 30 $\mu\mu\text{c}\alpha$ /gram and 80 $\mu\mu\text{c}\beta$ /gram, were normal. The alpha and beta activities in bottom silt from the storage lagoon were three to five times greater than normal. The increased activity represents an accumulation of radioactive nuclides from the water stored in the lagoon. This is indicated by the presence of 28 μg uranium/gram and 6.3 $\mu\mu\text{cSr}^{90}$ /gram in the December lagoon sample, while bottom silt samples from other locations contained only about 3 μg /gram of uranium and less than 2 $\mu\mu\text{c}$ /gram of Sr^{90} .

The alpha activity in bottom silt from the Des Plaines River (about 22 $\mu\mu\text{c}$ /gram) was essentially the same above and below the mouth of Sawmill Creek (Table XII). Similar values were found in previous years, so there is no significant concentration of alpha activity from ANL waste water in the Des Plaines River bed below the Laboratory site. This was confirmed by uranium analyses of the below site samples obtained in May and September. These samples contained a normal concentration of 2.9 μg uranium/gram. The average beta activity in bottom silt below the Laboratory site, 81 $\mu\mu\text{c}$ /gram, was 16 $\mu\mu\text{c}$ /gram greater than the corresponding average above the ANL site. Four samples below site (May, July, September, October) contained beta concentrations 25 to 300% above normal. The rate of beta decay of the samples indicates that this increased activity was probably due to fission products from both fallout and Laboratory waste water. The May and September samples contained less than 2 $\mu\mu\text{c}$ /gram of Sr^{90} , so no significant accumulation of long-lived fission products is indicated.

FIGURE 6.

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT
FROM SAWMILL CREEK, OCTOBER, 1955.

Table XII

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT
FROM DES PLAINES RIVER, 1955

Date Collected	Above ANL Site		Below ANL Site	
	$\mu\mu\text{ca}/\text{gram}$	$\mu\mu\text{cb}/\text{gram}$	$\mu\mu\text{ca}/\text{gram}$	$\mu\mu\text{cb}/\text{gram}$
January 19	-	-	18	37
March 16	22	65	21	44
May 18	24	61	24	115
June 15	20	84	22	74
July 20	27	69	23	145
August 17	21	65	23	74
September 21	21	64	24	109
October 19	23	64	24	94
November 9	18	46	19	76
December 21	-	-	16	41
Average	22	65	21	81

Concentrations of alpha and beta activities in bottom silt from lakes and streams near ANL are given in Tables XIII and XIV. The average values, $26 \mu\mu\alpha/\text{gram}$ and $57 \mu\mu\beta/\text{gram}$, were similar to the concentrations found in similar samples in previous years. Small increases in beta activity, averaging about $25 \mu\mu\beta$, were observed in a few of the samples collected in June and October. These increases were probably due to fallout activity since the beta activity decayed, and no corresponding increase in alpha activity occurred.

Table XIII

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT FROM
LAKES AND STREAMS NEAR ANL, 1955

Lake or Stream	Location	March		June		October		December	
		$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$
Des Plaines River	Irving Park Road	22	85	-	-	16	49	9	33
Des Plaines River	Willow Springs Bridge	22	65	20	84	23	64	-	-
Des Plaines River	Lemont Road Bridge	21	44	22	74	24	94	-	-
Des Plaines River	Romeoville	24	77	-	-	24	106	13	28
Du Page River	Naperville	105	75	155	89	104	74	17	29
Du Page River	Channahon	24	63	25	114	34	61	25	55
Du Page River	Lisle	33	68	-	-	-	-	-	-
Du Page River, East Branch	Glen Ellyn	26	55	-	-	25	62	-	-
Fox River	Montgomery	18	82	-	-	10	32	4.0	16
Ill. & Mich. Canal	Channahon	25	56	21	52	27	65	16	41
Flag Creek	Willow Springs	16	50	6.0	24	12	30	12	33
Long Run Creek	Ill. Rt. 4A & 135th St.	24	51	-	-	22	61	25	56
Drainage Ditch	Andres	18	53	-	-	-	-	-	-
Saganaskee Slough	104th Ave. & Sag Canal	14	37	14	42	12	42	-	-
Calumet Lake	111th St., Chicago	24	78	7.0	43	15	38	22	53
Lake Michigan	98th St., Chicago	-	-	-	-	5.0	32	-	-

Table XIV

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT
NEAR ANL, 1955

Distance from ANL (miles)	Month	No. of Samples	$\mu\mu\alpha/\text{gram}$		$\mu\mu\beta/\text{gram}$	
			Max.	Av.	Max.	Av.
10	March	8	105	32	77	58
10	June	5	155	43	89	63
10	October	7	104	32	106	67
10	December	4	25	17	56	37
25	March	7	26	22	85	67
25	June	3	25	18	114	70
25	October	7	34	19	65	48
25	December	5	25	15	55	40
Average			26		57	

Total activity concentrations in bottom silt from the reference sampling sites are given in Table XV. Except for the beta activity in the Iroquois River sample, the values were uniformly low and similar to that found in previous years. The Iroquois River sample contained about 90 $\mu\mu\beta/\text{gram}$ more beta activity than samples from this location in 1954. The decay rate of beta activity in the 1955 sample indicated that the additional beta activity was due to fresh fission products.

Table XV

NONVOLATILE RADIOACTIVITY IN BOTTOM SILT FROM
REFERENCE SITES, 1955

Location	June		December	
	$\mu\mu\alpha/\text{gram}$	$\mu\mu\beta/\text{gram}$	$\mu\mu\alpha/\text{gram}$	$\mu\mu\beta/\text{gram}$
Magician Lake, Mich.	3.9	45	4.6	23
Lake Michigan, St. Joseph, Mich.	-	-	3.2	18
Shafer Lake, Indiana	6.8	33	18	48
Iroquois River, Iroquois, Ill.	20	155	-	-
Illinois River, Starved Rock State Park	2.9	6.7	1.6	1.6
Illinois River, Henry, Illinois	7.7	24	11	27
Lake Geneva, Wis.	1.5	24	3.0	15
Lake Delavan, Wis.	17	65	17	53
Average	9	50	8	27

D. Surface Soil

Concentrations of radioactivity in surface soil collected during the year are given in Tables XVI, XVII, and XVIII. All the samples collected on the ANL site were normal, and the average values, $22 \mu\mu\alpha/\text{gram}$ and $57 \mu\mu\beta/\text{gram}$, were not significantly different from the values found at the 10 and 25-mile sampling locations. No increases over previous years were noted. The alpha and beta activities in soil from the 10 and 25-mile sampling locations were normal and uniform, except for one sample collected in June near Naperville. This sample contained about five times the average alpha activity. This is apparently a local condition, since similar alpha activities were found at this location in 1954 and concentrations of activity above average are frequently found in bottom silt from the Du Page River near Naperville. The radioactive content of soil from the reference sites was also normal, and no important changes from previous years were noted. No significant amounts of fallout activity were noticed in any of the soil samples collected during 1955.

Table XVI

NONVOLATILE RADIOACTIVITY IN SOIL FROM ANL SITE, 1955

Date Collected	No. of Samples	$\mu\mu\alpha/\text{gram}$		$\mu\mu\beta/\text{gram}$	
		Max.	Av.	Max.	Av.
April 4	6	27	22	57	51
June 13	6	23	20	61	57
October 13	5	26	20	69	60
December 29	5	38	27	66	61
Average		22		57	

Table XVII

NONVOLATILE RADIOACTIVITY IN SOIL NEAR ANL, 1955

Distance from ANL (miles)	Month	No. of Samples	$\mu\mu\alpha/\text{gram}$		$\mu\mu\beta/\text{gram}$	
			Max.	Av.	Max.	Av.
10	March	7	24	22	68	55
10	June	5	36	20	55	48
10	October	5	118	35	84	53
10	December	6	29	22	83	58
25	March	7	24	21	67	51
25	June	3	27	24	66	54
25	October	5	20	15	71	51
25	December	3	24	20	60	56
Average			23		53	

Table XVIII

NONVOLATILE RADIOACTIVITY IN SOIL FROM
REFERENCE SITES, 1955

Location	June		December	
	$\mu\mu\alpha/\text{gram}$	$\mu\mu\beta/\text{gram}$	$\mu\mu\alpha/\text{gram}$	$\mu\mu\beta/\text{gram}$
Magician Lake, Mich.	15	31	14	42
St. Joseph, Mich.	-	-	10	27
Monticello, Ind.	23	50	20	51
Iroquois, Ill.	17	40	-	-
Starved Rock, Ill.	22	49	39	33
Henry, Ill.	17	40	19	42
Geneva, Wis.	17	47	17	49
Delavan, Wis.	16	43	7	21
Average	18	43	18	38

E. Plants

Collection of plants was limited to grass since it was available at all sampling locations and permitted comparison of results independent of the type of plant.

Concentrations of alpha and beta activities in grass from all sampling locations are given in Tables XIX, XX, and XXI. The average alpha activities were normal for samples from all locations and showed no significant changes from previous years. The beta activities in samples from all locations averaged two to four times higher in April and June than in October and December. The widespread occurrence of this increase and the relatively rapid beta decay of the more active samples indicated that the increase was due primarily to fresh fission product fallout. The average beta activity for the entire year was about 25 $\mu\mu\beta/\text{gram}$ higher than in 1953. In general, the beta activity in grass increased from 1953 to 1955 and was about the same this year as in 1952, a year of relatively high fallout activity.

Table XIX

NONVOLATILE RADIOACTIVITY IN
GRASS ON ANL SITE, 1955

Month	No. of Samples	$\mu\mu\alpha/\text{gram}$		$\mu\mu\beta/\text{gram}$	
		Max.	Av.	Max.	Av.
April	6	2.9	2.7	240	154
June	5	1.8	0.9	181	123
October	5	14.4	3.8	167	71
December	5	8.5	2.2	122	58
Average		2.4		104	

Table XX

NONVOLATILE RADIOACTIVITY IN GRASS
NEAR ANL, 1955

Distance from ANL (miles)	Month	No. of Samples	$\mu\mu\text{Ca}/\text{gram}$		$\mu\mu\text{C}/\text{gram}$	
			Max.	Av.	Max.	Av.
10	April	7	10.7	5.1	236	173
10	June	4	0.9	0.6	111	96
10	October	5	4.1	1.3	54	44
10	December	6	2.8	1.3	42	31
25	April	5	7.4	3.7	173	137
25	June	4	1.0	0.7	102	90
25	October	3	0.9	0.7	58	41
25	December	3	1.6	0.9	49	42
Average			2.1		89	

Table XXI

NONVOLATILE RADIOACTIVITY IN GRASS FROM
REFERENCE SITES, 1955

Location	June		December	
	$\mu\mu\text{Ca}/\text{gram}$	$\mu\mu\text{C}/\text{gram}$	$\mu\mu\text{Ca}/\text{gram}$	$\mu\mu\text{C}/\text{gram}$
St. Joseph, Mich.	-	-	1.4	55
Magician Lake, Mich.	0.6	89	0.9	42
Monticello, Indiana	0.5	98	1.1	32
Iroquois, Ill.	1.1	172	-	-
Starved Rock, Ill.	0.8	175	4.4	58
Delavan, Wis.	0.6	100	0.4	72
Average	0.7	127	1.6	52

Several of the grass samples were analyzed for uranium and Sr^{90} . The results are given in Tables XXII and XXIII. The uranium content in grass from the ANL site was about the same as that in grass obtained away from the Laboratory. Uranium accounted for 5 to 10% of the total alpha activity in all samples analyzed.

Except for one sample collected at ANL in October, the Sr^{90} content of all samples analyzed was between 0.65 to 1.5 $\mu\mu\text{C}/\text{gram}$, and this range is probably normal for the Chicago area. The October sample

contained $6.5 \mu\mu\text{c}/\text{gram}$ of Sr^{90} and was collected from the contaminated water storage lagoon at ANL at a time when it was dry. This relatively high concentration of Sr^{90} is reasonable in view of the high beta activities found in water and bottom silt from the lagoon and is, of course, the result of the use to which this lagoon is put.

Table XXII

URANIUM CONTENT OF GRASS, APRIL 1955

Location	Uranium Content ($\mu\mu\text{c}/\text{gram}$)	Total Alpha Activity ($\mu\mu\text{c}/\text{gram}$)	% Alpha Activity Due to Uranium
Naperville, Ill.	0.54	8.5	6.4
Romeoville, Ill.	0.56	7.1	7.6
Flag Creek, Ill.	0.70	10.7	6.9
Delavan, Wis.	0.05	0.7	7.1
ANL	0.14	2.4	5.8
ANL	0.24	2.4	10
ANL	0.15	2.9	5.2

Table XXIII

STRONTIUM-90 CONTENT OF GRASS, 1955

Location	Month	Sr^{90} ($\mu\mu\text{c}/\text{gram}$)
Willow Springs	April	1.1 ± 0.3
Flag Creek	April	1.5 ± 0.3
ANL	April	1.2 ± 0.3
ANL	June	1.3 ± 0.2
ANL	June	0.65 ± 0.22
ANL	October	6.5 ± 1.0