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ENVIRONMENTAL RADIOACTIVITY AT
ARGONNE NATIONAL LABORATORY

Report for the Year 1957

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ENVIRONMENTAL RADIOACTIVITY AT ARGONNE NATIONAL LABORATORY

Report for the Year 1957

I. SUMMARY

Concentrations of radioactivity in several types of materials collected from the ANL site and from locations approximately 10, 25, and 100 miles from the Laboratory are given in this report. The principal purpose of this work was to determine if any radioactive materials were released to the environment by Argonne National Laboratory. In order to evaluate this, it was also necessary to determine the natural concentration of radioactivity in the environment and the contribution of fission product fallout to the total activity.

The sampling locations on and near the site are given in Part II. 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 radioactive elements and nuclides. The average total alpha and beta activities found in water, lake and stream beds ("bottom silt"), soil, and plants during 1957 are summarized in Figures 1-3. For purposes of comparison, Figures 4-7 give the results obtained on similar samples from 1952 through 1957. The long-lived alpha and beta activities found in air filter samples from 1952-57 are given in Section III-B of this report.

Fission product activity from fallout was found in all types of samples from most locations, with the maximum amount of fallout occurring from July through October. Radioactivity originating at ANL was found in water and bottom silt obtained from Sawmill Creek below the Argonne waste-water outfall. Water from this location contained an average of 12 micromicrocuries ($\mu\mu\text{c}$) of alpha activity per liter, or $9 \mu\mu\text{c}/\text{l}$ higher than water collected from Sawmill Creek above the Laboratory site. This increase is attributed primarily to uranium added to the stream in ANL waste water. About 90% of the samples obtained below outfall contained amounts of uranium above normal. The average uranium concentration in water from this location was $23 \mu\mu\text{c}/\text{l}$, or 0.3% of the maximum permissible concentration (MPC)*

*The concentrations of radioactivity attributable to Argonne operations were quite low, but it may be of interest to compare them with some published maximum permissible concentrations. The MPC's used in this report are those given in Title 10, Part 20, of the Federal Register and apply to the dissemination of radioactivity to unrestricted areas by installations licensed by the AEC. For most nuclides the values given in the Federal Register are 10% of those given in National Bureau of Standards Handbook 52, and, therefore, usually agree with recommendations made by the International Committee on Radiological Protection. The MPC's for water apply to drinking water only, and it should be emphasized that Sawmill Creek water is not used for human consumption.

Figure 1

AVERAGE RADIOACTIVITY IN SURFACE WATER, 1957

Figure 2

AVERAGE RADIOACTIVITY IN BOTTOM SILT, 1957

Figure 3

AVERAGE RADIOACTIVITY IN SOIL AND PLANTS, 1957

Figure 4

AVERAGE RADIOACTIVITY IN SURFACE WATER, 1952-57

Figure 5

AVERAGE RADIOACTIVITY IN BOTTOM SILT, 1952-57

Figure 6

AVERAGE RADIOACTIVITY IN SURFACE SOIL, 1952-57

Figure 7

AVERAGE RADIOACTIVITY IN PLANTS, 1952-1957

for drinking water. A smaller contribution to the alpha activity in below-site water was made by plutonium added to the Creek in ANL waste water. The average plutonium concentration at this location was $2.3 \mu\mu\text{c}/\text{l}$. This average value was 1.4% of the MPC, while the maximum plutonium concentration found, $25 \mu\mu\text{c}/\text{l}$, amounted to 16% of the MPC. Plutonium was not detected in any of the above-site samples.

Fission products from fallout were found in Creek water from both locations; beta activity from Laboratory waste water was found only below the outfall. The total beta activity averaged $45 \mu\mu\text{c}/\text{l}$ in below-site water and $29 \mu\mu\text{c}/\text{l}$ in above-site water. The average contribution of fallout and ANL waste water to the total beta activity in the stream was approximately $15 \mu\mu\text{c}/\text{l}$ from each source. The remaining activity is attributed to naturally occurring radioactive nuclides, including K^{40} .

Concentrations of Sr^{90} greater than $2 \mu\mu\text{c}/\text{l}$ were found only in below-site water. This nuclide was added to the Creek in ANL waste water. The average Sr^{90} concentration, $3.0 \mu\mu\text{c}/\text{l}$, was about 4% of the MPC. Other fission products were found at both locations and were contributed at various times by both fallout and Laboratory waste water. The individual results and the number of samples in which each nuclide was detected are given in Part III.

The activity added to Sawmill Creek in ANL waste water and fallout had no detectable effect on the radioactivity in the Des Plaines River water. The average total alpha activities (about $1.9 \mu\mu\text{c}/\text{l}$), uranium concentrations ($1.4 \mu\mu\text{c}/\text{l}$), and beta activities (about $33 \mu\mu\text{c}/\text{l}$) were essentially the same above and below the ANL site.

The activities found in the natural ponds on the ANL site were not significantly different from those in lakes and streams near the Laboratory. Concentrations of total alpha activity averaged $1.4 \mu\mu\text{c}/\text{l}$ in the on-site and $1.5 \mu\mu\text{c}/\text{l}$ in the off-site samples. The corresponding results for beta activity were 22 and $21 \mu\mu\text{c}/\text{l}$. Similar results were obtained in previous years. The storage lagoon for contaminated waste water on the ANL site contained $2\text{-}3 \mu\mu\text{c}\alpha/\text{l}$ and $10\text{-}50 \mu\mu\text{c}\beta/\text{l}$ in excess of normal surface water. However, many water samples containing similar concentrations of beta activity derived from fallout were also found during the year. The total activities in water collected from the reference sites ranged from 0.1 to $1.5 \mu\mu\text{c}\alpha/\text{l}$ and 3.7 to $80.3 \mu\mu\text{c}\beta/\text{l}$. Samples containing the higher concentrations of beta activity decayed at a more rapid rate than the lower samples, indicating a larger amount of fission product activity in the former. No important changes from earlier years were noted.

The total activities found in bottom silt varied considerably with location and time of sampling. Samples containing sand and other relatively large particles were generally lower in activity than material

consisting primarily of clay. Some of the samples collected from Sawmill Creek below the waste-water outfall contained activity added to the Creek in ANL waste water. These samples contained from 61 to 398 $\mu\mu\alpha/\text{g}$ and from 110 to 1157 $\mu\mu\beta/\text{g}$, as compared with normal values of 10-30 $\mu\mu\alpha/\text{g}$ and 50-90 $\mu\mu\beta/\text{g}$. The presence of contamination in these samples was confirmed by additional analyses on the two below-site samples of highest activity. The latter contained 85 and 101 $\mu\text{gU/g}$, 93 and 149 $\mu\mu\text{Pu/g}$, and 8.4 and 13.5 $\mu\mu\text{cSr}^{90}/\text{g}$. Bottom silt from other locations contained about 2.5 $\mu\text{gU/g}$ and less than 0.3 and 1.5 $\mu\mu\text{c/g}$ of plutonium and Sr^{90} , respectively. As was found for flowing water, the increased activity in Sawmill Creek had no significant effect on the radioactive content of the Des Plaines River bed. Bottom silt from the Des Plaines River averaged 21 $\mu\mu\alpha/\text{g}$ and 69 $\mu\mu\beta/\text{g}$ above the ANL site and 23 $\mu\mu\alpha/\text{g}$ and 64 $\mu\mu\beta/\text{g}$ below site.

The bed of the storage lagoon for contaminated waste water contained 10 to 20 times the normal concentration of alpha and beta activities as a result of the use made of this lagoon. Bottom silt from the natural lagoons on the ANL site and from the lakes and streams near the Laboratory averaged about 25 and 65 $\mu\mu\text{c/g}$ of alpha and beta activities respectively. These values were similar to those found in previous years. The average alpha activity in the reference site samples was 6 $\mu\mu\text{c/g}$, approximately the same as found in 1955 and 1956. The average beta activity, 21 $\mu\mu\text{c/g}$, was about 15 $\mu\mu\text{c/g}$ less than the average for the years 1952-1956, but the total beta activity is, of course, greatly influenced by the amount of fallout at the time of sampling.

Most soil samples contained normal activities: 20-30 $\mu\mu\alpha/\text{g}$ and 40-80 $\mu\mu\beta/\text{g}$. Increases in beta activity of 25 to 150 $\mu\mu\text{c/g}$ due to fallout activity were found in some of the samples collected on and near the site during June, August and October. The beta activities in these samples decayed to normal values in about four months. One soil sample, collected on the Laboratory site near a uranium storage shed, contained approximately 20 $\mu\mu\text{c/g}$ in excess of the normal uranium concentration. Except for this sample, no evidence of contamination originating at Argonne was found in soil.

The alpha activities in grass during 1957 were uniformly low, averaging 1.6 $\mu\mu\text{c/g}$ at all locations. The beta activity in grass collected on and near the ANL site averaged 170 and 132 $\mu\mu\text{c/g}$, respectively. This was about 70 $\mu\mu\text{c/g}$ greater than found in other years; this increase was evidently due to above-normal concentrations of fission product fallout in samples collected in April, March, August, and October. The beta activities in all samples decayed to normal values (40-80 $\mu\mu\text{c/g}$) regardless of the original activity. Grass from the reference sites contained an average of only 57 $\mu\mu\beta/\text{g}$. However, samples were not collected from the reference sites during the months when increased beta activity was found on and near the site.

Airborne particulate radioactivity was collected at five locations on the Argonne site and, beginning in May, 1957, at three locations near the Laboratory. The activities remaining on the filter papers after the decay of thoron and radon daughters were due primarily to fission products from nuclear detonations (for most of the beta activity) and to long-lived naturally occurring radioactive nuclides present in dust in the air (for the alpha activity and a small fraction of the beta activity). The alpha activities have remained quite constant. The average annual alpha activity three days after sample collection ranged from 0.007 to 0.010 micromicrocurie per cubic meter ($\mu\mu/\text{M}^3$) from 1953 to 1957. The beta activity was more variable. The average beta activities in the weekly samples were $1.2 \mu\mu\text{c}/\text{M}^3$ in 1953 and $0.4 \mu\mu\text{c}/\text{M}^3$ in 1954. Since 1954 the beta activity increased approximately $0.6 \mu\mu\text{c}/\text{M}^3$ per year to an average of $2.1 \mu\mu\text{c}/\text{M}^3$ in 1957, probably because nuclear detonations were carried out over longer periods of time in recent years. Short-term increases in beta activity, accompanied by an increase in the decay rate, were observed during all years. These increases were, therefore, due to fission products of recent origin.

No consistent or important differences between the off-site and on-site air filter samples were noted, and no significant concentrations in air due to ANL operations were found. The alpha and beta activities at all locations were about 0.2% of the MPC for unknown mixtures of activities.

II. PROGRAM AND PROCEDURES

This report presents the results of the environmental monitoring program at Argonne National Laboratory for the year 1957, together with some of the results obtained from air samples collected earlier. The purposes of the program are to evaluate the natural radioactive contents of the ANL site and its environment, and to determine the magnitude and origin of any radioactivity above the natural levels. Of particular interest is the detection of any radioactive materials released to the environment by Argonne National Laboratory. The radioactive content of the environment was measured by performing radiochemical analyses and total activity counting on the numbers and types of samples given in Table I.

TABLE I
SAMPLES COLLECTED IN 1957

Water	349	Plant	100
Precipitation	122	Air Filter	644
Soil	109	Animal	13
Bottom Silt	162		

Since the most probable means of dispersal of radioactive contamination are by water and air, most of the samples were of these types. Samples were collected from the Argonne site and from locations approximately 10, 25, and 100 miles from the Laboratory, as indicated in Figures 8 and 9. Samples collected from the 10 and 25-mile locations ("near" the Laboratory) were expected to indicate the extent and direction of radioactive contamination in the event that significant amounts of activity had been released as a result of operations at Argonne. Samples from the 100-mile locations (termed reference sites) were originally intended to serve as continuous checks for sample contamination during collection, analysis, and storage. These purposes have been realized for alpha-activity measurements, but, as a result of generalized fission product fallout, beta-activity measurements at the levels encountered were more difficult to interpret. The latter measurements have served to indicate the extent and magnitude of fission product fallout; but by making the proper comparisons between off-site and on-site samples, by measuring beta-activity decay rates, and by analyzing for fission products of various half-lives, it was usually possible to distinguish between beta activity from nuclear explosions, Argonne operations, and natural sources.

The measurements of total activity were obtained by counting thick samples (10 to 75 mg/cm²) in nylon-windowed alpha and beta counters. For all samples except air filters, counting rates were converted to disintegration rates by applying corrections determined for Pu²³⁹ (for alpha particles) and Tl²⁰⁴ (for beta particles) under the same conditions used in counting samples. The results obtained in this way represent the true disintegration rates only if the particles emitted by the samples have the same energies as those emitted by Pu²³⁹ and Tl²⁰⁴. True disintegration rates cannot be obtained from measurements of total activity, since the samples contained mixtures of nuclides of varying and unknown composition and at low concentrations. However, these measurements of total activity can be made rapidly and are useful in the intercomparisons of samples and in determining which samples should be analyzed for specific elements and nuclides.

The long-lived activities given for air filters in Section III-B were obtained by applying correction factors measured for radon daughters to the counting rates. The disintegration rates obtained in this way represent the radon concentrations in air that would give rise to the observed counting rates on the filters papers. As was the case for the other types of samples, true disintegration rates cannot be obtained for air-filter samples by total alpha and beta counting. However, this type of counting permits the rapid analysis of large numbers of samples and the results are useful in the intercomparison of samples and in the comparison of long-lived activity with radon concentration in the air.

Specific fission product analyses were made by separating the desired element with carrier added and counting in an anti-coincidence

Figure 8

Sampling Locations on the Site of Argonne National Laboratory

Figure 9

Sampling Locations near Argonne National Laboratory

shielded beta counter. The separation procedures used were those given by Coryell and Sugarman,* suitably modified for use with the types of samples encountered. Counting rates were converted to disintegration rates by applying experimentally determined counting yields for each fission product nuclide. Concentrations of Sr^{89} and Sr^{90} and of Ce^{141} and Ce^{144} in the separated strontium and cerium fractions were calculated by an IBM-650 Computer from the total beta counting rates at various times after separation.

Uranium analyses were made with a fluorophotometer, and the results were converted to micromicrocuries, assuming the natural isotopic composition. Plutonium and thorium analyses were determined by thenoyl-trifluoroacetone (TTA) extraction. After coprecipitation of both elements with cerium fluoride and dissolution of the precipitate, plutonium was reduced to the +3 state and the thorium extracted with TTA. The plutonium was then oxidized to the +4 state and extracted into TTA solution. After suitable sample preparation, the separated plutonium and thorium activities were counted in a windowless alpha counter.

Additional information on the sampling program, instrumentation, counting techniques, and analytical procedures may be found in the previous reports in this series: ANL-5069, 5289, 5446, 5684, and 5808. The helpful assistance of John F. Ege, Jr. and John H. Pingel in the preparation of the manuscript is gratefully acknowledged.

III. RADIOACTIVITY IN ENVIRONMENTAL SAMPLES

A. Rain

The total alpha and beta activities in rain collected on the ANL site are given in Table II. The alpha activity that decayed during the first few days after the end of the rainfall was due to radon and thoron daughters. The alpha activity remaining after one week was due primarily to natural activities present in dust in the air or in dust blown into the rain collector. Contributions to the total beta activity were made by the sources mentioned above and also by natural potassium and fallout from nuclear detonations. Analyses for potassium and fission products have shown that the bulk of the beta activity remaining after three days was derived from fallout.

The monthly variations shown in the table may be correlated with announced detonations. Thus, the high increases in beta activity during the summer months resulted from test explosions during that period. This was confirmed from the age of the fission products as calculated by assuming a $T^{-1.2}$ decay rate. From June through most of October the calculated ages were less than thirty days, while most of the November and December samples contained fission products produced during September and October.

*"Radiochemical Studies: The Fission Products," C. D. Coryell and N. Sugarman, Eds., McGraw-Hill Book Co. Inc (New York, 1951)

TABLE II
NONVOLATILE RADIOACTIVITY IN RAINWATER AT ANL, 1957

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	$100 \mu\mu\text{c/liter}$		Samples Counted	$100 \mu\mu\text{c/liter}$	
			Max.	Av.		Max.	Av.		Max.	Av.		Max.	Av.
January	11	9	31.0	11.7	11	28.0	10.9	9	33.7	13.8	11	33.2	14.0
February	8	7	10.1	4.7	8	9.6	3.8	7	14.5	7.8	8	13.4	6.4
March	5	5	17.9	8.0	5	3.8	1.9	5	27.4	10.5	5	16.0	7.3
April	19	15	22.9	5.3	19	10.1	1.7	15	91.5	17.2	19	36.1	9.5
May	12	11	21.0	4.1	11	18.0	3.0	11	34.4	8.1	11	32.9	7.5
June	18	17	79.0	12.3	18	11.0	2.1	17	61.3	13.6	18	46.6	10.7
July	7	7	22.8	5.5	7	6.3	1.8	7	192	70	7	135	56
August	12	7	40.0	13.8	11	36.9	9.4	12	513	106	12	350	79
September	7	7	7.4	2.8	7	4.1	1.6	7	195	55	7	138	39
October	8	8	14.2	2.8	8	8.0	2.0	8	82.6	20.5	8	66.0	16.0
November	8	7	3.4	1.5	8	1.5	0.6	8	5.6	2.6	8	5.0	1.3
December	7	6	8.9	3.3	8	8.9	2.5	6	11.3	6.3	7	10.6	5.1

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

In general, high concentrations of beta activity were associated with recent detonation dates. It should be pointed out that an accurate detonation date can be obtained from the decay rate only if most of the activity carried down by a rainfall was derived from one explosion, or from a very few explosions occurring within a short time interval.

The increase in beta activity during the summer and fall months was also noted in other types of samples, so that beta-activity concentrations in rain were useful in interpreting beta activities in other samples. The general trend in fallout activity in rainfall may be seen from Figure 10. Except for a few months of very high activity during each year there has been a general increase in the past two years from a median value of about $200 \mu\mu\text{c/l}$ to about $700 \mu\mu\text{c/l}$. This was probably the result of bomb testing being conducted over a larger fraction of the year during 1956 and 1957. Since a small fraction of the rainfalls carry down most of the activity during any one year, the total amount of beta activity carried down each year has not increased as the median value has. During 1955 and 1957 the total activity, as calculated from the one-week activities in each sample, was about 1200 millicuries per square mile. For 1953, 1954, and 1956 the corresponding value was about 600, while in 1952 about 11,000 mc/mi^2 were found in the rains. About 95% of the latter amount was found in the samples collected in June, 1952.

B. Air Filters

Air-borne particulate matter was sampled at five locations on the Laboratory site, and, beginning in May, at three locations off the Laboratory site. To collect the sample, air was filtered through Hollingsworth-Vose No. 70 filter paper using a Filter-Queen Vacuum Cleaner modified to draw air through the paper, or a Sutorbilt Air Sampler. A rotameter was used to measure the air flow; the Filter-Queen sampler operated at 15 cubic

Figure 10

AVERAGE MONTHLY BETA ACTIVITY IN RAINWATER, 1952-57

meters per hour and the Sutorbilt sampler at 30 cubic meters per hour. Twenty-four hour samples were collected with one sampler on the Laboratory site to record short-term changes in air activity. The remaining on-site samplers, and all off-site samplers, were operated for a one-week sampling period. The instruments were operated continuously except for equipment failures and the few minutes required to change filter papers. 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 the polystyrene layer was 50 micrograms per cm^2 . The area of the paper was 200 cm^2 . A circle, 2 inches in diameter (20 cm^2), was cut from the center of the paper, mounted on a stainless steel counting planchet, and counted for alpha and beta activities in a nylon-window proportional counter. Monthly summaries of weekly air-filter samples collected from 1953 through 1957 and daily samples collected in 1957 are given in Tables III to VIII. The results for daily samples collected from 1953-1956 were given in ANL-5808. The results given in the tables were calculated from the counting rates three and seven days after the end of

TABLE III

TOTAL ALPHA AND BETA ACTIVITIES IN WEEKLY AIR FILTER
SAMPLES COLLECTED ON ANL SITE, 1953

Month	$\mu\mu\text{c}/\text{M}^3$ after 3-Day Decay					$\mu\mu\text{c}/\text{M}^3$ after 7-Day Decay				
	No. of Samples	Alpha Act.		Beta Act.		No. of Samples	Alpha Act.		Beta Act.	
		Max.	Av.	Max.	Av.		Max.	Av.	Max.	Av.
January	0	-	-	-	-	15	0.007	0.004	0.13	0.08
February	3	0.009	0.007	0.11	0.09	12	.007	.004	0.09	0.06
March	12	.009	.007	3.8	0.8	12	.007	.005	2.3	0.6
April	11	.010	.007	1.1	0.5	11	.006	.005	0.82	0.41
May	14	.030	.011	4.2	1.9	15	.024	.007	2.7	1.3
June	12	.036	.013	28.7	5.6	12	.036	.007	23.3	4.5
July	9	.015	.009	2.1	1.6	11	.006	.004	2.0	1.3
August	15	.024	.012	0.92	0.65	15	.014	.005	0.84	0.60
September	11	.020	.016	2.8	2.0	12	.011	.006	2.4	1.7
October	13	.038	.018	1.9	0.8	13	.017	.008	1.7	0.7
November	10	.025	.018	0.48	0.37	10	.010	.007	0.44	0.33
December	4	.006	.005	0.20	0.15	8	.011	.004	0.21	0.14
Average		0.010		1.2			0.006		1.0	

TABLE IV

TOTAL ALPHA AND BETA ACTIVITIES IN WEEKLY AIR FILTER
SAMPLES COLLECTED ON ANL SITE, 1954

Month	$\mu\mu\text{c}/\text{M}^3$ after 3-Day Decay					$\mu\mu\text{c}/\text{M}^3$ after 7-Day Decay				
	No. of Samples	Alpha Act.		Beta Act.		No. of Samples	Alpha Act.		Beta Act.	
		Max.	Av.	Max.	Av.		Max.	Av.	Max.	Av.
January	4	0.012	0.008	0.11	0.10	4	0.007	0.006	0.11	0.10
February	10	.143	.019	.39	.12	10	.005	.004	.12	.09
March	8	.009	.005	.69	.31	9	.006	.004	.52	.24
April	12	.013	.011	.57	.30	12	.008	.005	.50	.26
May	10	.032	.012	.34	.20	10	.014	.006	.32	.16
June	11	.011	.010	.79	.35	12	.004	.003	.72	.30
July	11	.013	.010	.46	.27	11	.007	.004	.43	.24
August	10	.010	.007	.40	.33	11	.008	.004	.40	.30
September	13	.025	.015	2.3	.5	12	.006	.003	.50	.26
October	8	.019	.008	2.0	.7	14	.012	.005	1.2	.6
November	17	.029	.011	2.2	1.2	17	.013	.007	1.8	1.0
December	15	.011	.005	0.93	0.61	15	.006	.003	0.87	0.56
Average		0.010		0.4			0.005		0.3	

TABLE V

TOTAL ALPHA AND BETA ACTIVITIES IN WEEKLY AIR FILTER
SAMPLES COLLECTED ON ANL SITE, 1955

Month	$\mu\mu\text{c}/\text{M}^3$ after 3-Day Decay					$\mu\mu\text{c}/\text{M}^3$ after 7-Day Decay				
	No. of Samples	Alpha Act.		Beta Act.		No. of Samples	Alpha Act.		Beta Act.	
		Max.	Av.	Max.	Av.		Max.	Av.	Max.	Av.
January	13	0.009	0.005	0.47	0.29	10	0.006	0.005	0.42	0.28
February	12	.013	.006	2.1	0.6	13	.013	.005	1.3	0.7
March	19	.020	.007	3.8	1.2	19	.007	.005	2.4	0.9
April	18	.020	.008	2.0	1.3	17	.009	.005	1.8	1.0
May	22	.019	.009	12.2	3.6	19	.013	.004	9.2	2.7
June	18	.023	.008	2.3	1.0	18	.007	.004	2.2	0.9
July	19	.031	.011	1.3	0.5	17	.023	.006	0.88	0.42
August	17	.019	.009	0.42	0.29	18	.008	.004	0.42	0.25
September	13	.021	.007	0.32	0.19	14	.006	.003	0.30	0.18
October	9	.019	.006	0.17	0.12	15	.009	.003	0.17	0.11
November	15	.007	.004	1.0	0.3	16	.006	.003	0.71	0.28
December	18	.010	.005	1.7	0.9	15	.006	.004	1.6	0.8
Average		0.007		0.8			0.004		0.7	

TABLE VI

TOTAL ALPHA AND BETA ACTIVITIES IN WEEKLY AIR FILTER
SAMPLES COLLECTED ON ANL SITE, 1956

Month	$\mu\mu\text{c}/\text{M}^3$ after 3-Day Decay					$\mu\mu\text{c}/\text{M}^3$ after 7-Day Decay				
	No. of Samples	Alpha Act.		Beta Act.		No. of Samples	Alpha Act.		Beta Act.	
		Max.	Av.	Max.	Av.		Max.	Av.	Max.	Av.
January	15	0.012	0.006	2.3	1.7	12	0.014	0.005	2.1	1.6
February	13	.006	.004	1.5	0.9	12	.006	.005	1.4	0.9
March	16	.010	.006	1.3	1.0	15	.007	.005	1.2	0.9
April	12	.016	.009	2.2	1.4	8	.008	.005	2.2	1.2
May	13	.030	.008	1.5	1.0	12	.025	.006	1.4	1.0
June	6	.025	.009	1.4	0.8	6	.005	.003	1.3	0.8
July	10	.038	.017	1.1	0.7	11	.021	.008	1.0	0.6
August	14	.029	.010	1.5	0.9	13	.028	.005	1.4	0.8
September	14	.033	.016	7.9	3.1	14	.010	.005	6.1	2.5
October	12	.033	.016	3.5	2.0	15	.013	.008	3.6	2.1
November	14	.026	.012	1.3	0.9	15	.010	.005	1.1	0.8
December	12	.022	.007	1.7	1.0	16	.021	.006	1.5	0.8
Average		0.010		1.3			0.006		1.2	

TABLE VII
TOTAL ALPHA AND BETA ACTIVITIES IN WEEKLY AIR
FILTER SAMPLES, 1957

Month	Location	No. of Samples	$\mu\mu\text{c}/\text{M}^3$ after 3-Day Decay				$\mu\mu\text{c}/\text{M}^3$ after 7-Day Decay			
			Alpha Act.		Beta Act.		Alpha Act.		Beta Act.	
			Max.	Av.	Max.	Av.	Max.	Av.	Max.	Av.
January	ANL	17	0.012	0.005	1.3	1.0	0.008	0.004	1.2	0.9
February	ANL	7	.010	.007	1.4	1.1	.008	.005	1.3	1.1
March	ANL	14	.012	.006	2.5	1.4	.007	.005	2.2	1.3
April	ANL	18	.021	.008	2.7	1.6	.008	.005	2.7	1.6
May	ANL	18	.017	.008	3.4	2.0	.010	.006	3.3	1.9
	Near ANL	4	.007	.005	1.7	1.1	.006	.004	1.6	1.1
June	ANL	10	.016	.009	3.0	1.9	.007	.004	2.8	1.6
	Near ANL	4	.009	.006	1.5	1.3	.005	.004	1.4	1.3
July	ANL	13	.022	.010	8.9	3.1	.011	.005	2.8	1.9
	Near ANL	8	.030	.015	2.8	2.0	.005	.004	2.4	1.5
August	ANL	16	.042	.016	11.1	3.6	.015	.005	7.9	3.0
	Near ANL	4	.016	.010	9.3	5.3	.017	.010	7.1	3.9
September	ANL	10	.016	.008	8.5	4.1	.006	.003	6.1	3.1
	Near ANL	8	.006	.004	4.9	2.6	.004	.003	5.7	2.3
October	ANL	13	.043	.010	7.7	3.0	.009	.003	6.3	2.4
	Near ANL	6	.026	.008	2.7	1.7	.005	.003	2.5	1.5
November	ANL	10	.018	.006	3.0	1.3	.006	.003	3.0	1.2
December	ANL	7	.007	.005	2.0	1.0	.006	.004	1.5	0.9
	Near ANL	7	.007	.003	1.6	1.0	.006	.003	1.6	0.8
Average	ANL		0.008 (0.009)*		2.1 (2.7)*		0.005 (0.004)*		1.7 (2.2)*	
	Near ANL		0.007		2.1		0.004		1.7	

*ANL samples, May through October and December only.

the filtering period for weekly samples and after three days for daily samples. The factors used to convert counting rates to disintegration rates, and the validity of the results, are discussed in ANL-5808. The weekly samples were also counted during the first day after the sampling period, and the radon and thoron concentrations obtained from these counting rates will be reported at a later date.

The activities remaining after three days were due primarily to fission products (for most of the beta activity) and to long-lived naturally occurring radioactive nuclides (for the alpha activity and a small fraction of the beta activity). The beta activities showed periodic fluctuations, with increases observed during periods of nuclear detonations. A comparison

TABLE VIII
LONG-LIVED RADIOACTIVITIES IN 24-HOUR
AIR-FILTER SAMPLES COLLECTED ON
ANL SITE, 1957

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	25	0.020	0.009	2.2	1.1
February	25	0.047	0.008	2.7	1.2
March	31	0.068	0.016	4.1	1.5
April	27	0.068	0.018	2.8	1.2
May	29	0.097	0.016	6.0	2.1
June	30	0.071	0.022	3.4	1.8
July	23	0.092	0.038	25.3	3.5
August	30	0.451	0.044	15.5	3.4
September	27	0.092	0.021	12.9	3.1
October	21	0.050	0.029	12.7	2.5
November	28	0.032	0.013	9.2	1.4
December	28	0.090	0.022	4.1	1.1
Average		0.021		2.0	

of the third and seventh-day activities indicated that these increases were associated with shorter-lived activities than were present during periods of lesser fallout. The long-term trend for fission product activity in air may be seen from the summary in Table IX.

TABLE IX
ANNUAL AVERAGE OF "THIRD DAY" BETA ACTIVITY
IN AIR ON ANL SITE

Year	Weekly Samples		Daily Samples	
	No. of Samples	($\mu\mu\text{c}/\text{M}^3$)	No. of Samples	($\mu\mu\text{c}/\text{M}^3$)
1953	114	1.2	322	1.4
1954	129	0.4	345	0.5
1955	193	0.8	345	1.0
1956	151	1.3	345	1.6
1957	153	2.1	324	2.0

The beta activity has increased slowly but consistently from 1954 to 1957, following a decrease from 1953 to 1954. The increase in the average in recent years has not been accompanied by an increase in the maximum values during periods of bomb testing, but by an increase in the median value. For example, the highest individual result, $127 \mu\mu\text{c}/\text{M}^3$, was obtained in May, 1953, while the maximum value during 1957 was only

25.3 $\mu\mu\text{c}/\text{M}^3$. However, in 1953 monthly averages less than 1 $\mu\mu\text{c}/\text{M}^3$ were found during seven months, while in 1957 the minimum monthly average was 1.1 $\mu\mu\text{c}/\text{M}^3$. The reason for this trend is probably the same as that given for a similar trend in rain. That is, during recent years, testing has been conducted over a larger fraction of the year.

There was good agreement between the beta activity in the weekly and daily air-filter samples during periods of low fallout. However, when the concentration of short-lived fission products increased, differences in beta activities between the two types of samples were noted. At such times the collection of a few high-activity particles on a filter paper will have a large effect on the results. For the weekly air filters, the time during the sampling period when such particles are collected becomes very important, and quantitative agreement between the two types of samples cannot be expected. The daily samples probably give a more accurate picture of the total amount of fallout. The collection of weekly samples, however, permits the analysis of a larger number of samples with inexpensive air samplers and fewer counters than would otherwise be possible. A large number of locations can be monitored in this way, and, since the papers are changed on different days at the various locations, the times at which changes in activity occur can still be obtained. In addition, the weekly samples will be useful in determining the concentrations of long-lived fission products in air. There was a consistent difference in long-lived alpha activity between the weekly and daily air filters on the site as a result of differences in sample thickness for which adequate corrections had not been made. However, each type of sample yields consistent results and comparison may be made between samples collected for the same period of time. The average third-day alpha activity in the daily samples was 0.02 in 1957, and 0.03 from 1953-1956; the corresponding results for the weekly samples ranged from 0.007 to 0.010. Thus, the alpha activities have remained quite constant, and consistent for each collection period, and do not vary with the beta activities.

Samplers were located on the periphery of the site as well as near buildings containing large amounts of radioactive materials. One sampler was located between the EBWR and CP-5 reactors. No significant or consistent differences between samples obtained at the various on-site locations could be detected. Gaseous contaminants, including tritium and tritiated water, were not collected by these samples. A program is underway to determine these materials in air.

In May, samples collection was begun at locations off the Laboratory site. Samples were collected at Stateville Penitentiary, 10 miles southwest of the ANL site; Suburban Cook County Tuberculosis Sanitarium near Hinsdale, 6 miles northwest of the site; and Tinley Park State Hospital, 13 miles southeast of the site. These locations were obtained through the cooperation of the Illinois Department of Public Health. As shown in

Table VII, the differences in beta activity between the off-site and on-site samples varied in magnitude and direction, averaging $0.6 \mu\mu\text{c}/\text{M}^3$ higher on the on-site. Variations in the amount of fallout collected at different locations may have contributed to these differences, since they were greater during periods of increased fallout and were greater after three-day decay than after seven-day decay. Another important variable was the type of air sampler used. Because of their greater mechanical reliability and durability, Sutorbilt Air samplers were used off the ANL site; Filter-Queen samplers were used on the site. Since the Sutorbilt samplers operate at twice the flow rate of the Filter-Queen instruments, a larger amount of dust was collected by the former. The same correction factors were used for samples collected by both instruments, so errors tending to give lower results with the Sutorbilt samplers were introduced in this way. The quantitative effects of these variables in sample collection are not known, but a study is underway to evaluate them. It is intended to replace the Filter-Queen samplers as the Sutorbilt samplers become available. The average alpha activity was approximately the same both off and on the Laboratory site, although some individual samples collected from different locations during the same time interval differed by factors of two to three. Since the amount of long-lived alpha activity collected on the filter paper is a function of the amount of dust in the air, differences due only to location may be expected.

From June through December air samplers were operated simultaneously at the top of the 120-foot high Meteorology Tower on the site and on the ground approximately 100 yards from the tower. The air intake on the latter sampler was located three feet from the ground. The tower samples were slightly, but consistently, higher than the sample collected near the ground. The averages for the tower samples were $0.005 \mu\mu\alpha/\text{M}^3$ and $0.68 \mu\mu\beta/\text{M}^3$; the corresponding values for the ground samples were $0.003 \mu\mu\alpha/\text{M}^3$ and $0.53 \mu\mu\beta/\text{M}^3$. The same self-absorption factors were used for both types of samples and, if the concentrations of particulate radioactivity were essentially the same at both heights, the additional self-absorption in the ground samples, due to the larger amount of material collected, would account for this difference.

C. Water

1. Sawmill Creek and Des Plaines River

Sawmill Creek was sampled above the Laboratory site (at square 15K in Figure 8) and below the Argonne waste water outfall (square 7M). Monthly summaries of the alpha activities found at both locations are given in Table X. The water collected below the outfall contained an average of $12 \mu\mu\alpha/1$, or about $9 \mu\mu\text{c}/1$ more than from above the site. This difference is attributed to activity added to the Creek in Argonne waste water and amounts to 9% of the maximum permissible concentration (MPL)

TABLE X
NONVOLATILE ALPHA ACTIVITIES IN SAWMILL CREEK WATER, 1957

Month	Location*	Total Alpha Activity			Uranium			Plutonium				Thorium			
		No. of Samples	μμc/liter		No. of Samples	c/liter		No. of Samples	Samples > 0.2 μμc/l			No. of Samples	Samples > 0.2 μμc/		
									No.	μμc/liter			No	μμc/liter	
			Max.	Av.		Max.	Av.			Max.	Av.			Max.	Av.
January	A	1	6.4	--	0	--	--	1	0	--	--	1	0	--	--
January	B	12	25.8	10.2	2	14.0	13.7	2	2	8.8	5.2	2	2	0.6	0.5
February	A	4	8.3	4.1	4	6.8	2.9	1	0	--	--	1	0	--	--
February	B	12	19.2	8.9	4	22.0	12.4	2	2	6.6	5.1	2	1	0.4	--
March	A	4	2.3	1.8	4	1.4	1.1	2	0	--	--	2	0	--	--
March	B	13	145	21	5	151	50	2	2	1.7	1.2	2	2	2.6	1.6
April	A	4	3.8	2.3	4	1.8	1.4	2	0	--	--	2	0	--	--
April	B	13	246	29	4	240	78	2	2	5.3	2.8	2	1	0.6	--
May	A	5	2.0	1.7	5	1.5	1.2	2	0	--	--	2	0	--	--
May	B	14	32.1	9.4	4	7.0	5.8	2	1	0.2	--	2	1	0.4	--
June	A	4	3.2	3.0	4	2.1	1.8	2	0	--	--	2	0	--	--
June	B	12	10.5	6.0	4	6.5	4.7	2	1	0.5	--	2	0	--	--
July	A	5	5.3	2.6	5	3.4	1.4	2	0	--	--	2	1	0.3	--
July	B	13	39.4	9.6	5	37.2	12.4	2	0	--	--	2	0	--	--
August	A	4	2.1	1.4	4	1.3	0.9	2	0	--	--	2	1	0.2	--
August	B	13	82.0	10.6	4	42.0	31.4	2	1	0.3	--	2	1	0.2	--
September	A	4	6.6	3.4	4	4.1	1.8	2	0	--	--	2	0	--	--
September	B	12	14.1	5.7	4	6.8	5.5	2	2	1.0	0.7	2	1	--	--
October	A	5	11.4	5.3	5	4.6	3.1	2	0	--	--	2	1	1.2	--
October	B	13	25.6	9.9	5	25.0	17.1	3	3	0.2	0.2	3	0	--	--
November	A	4	4.9	2.6	4	2.9	2.4	2	0	--	--	2	1	0.7	--
November	B	11	24.1	10.8	4	35.0	25.1	3	3	25.0	10.0	3	1	0.4	--
December	A	3	3.6	2.6	3	2.9	2.4	2	0	--	--	2	1	1.1	--
December	B	12	19.1	9.2	3	17.5	13.6	2	2	1.0	0.7	2	0	--	--
Average	A		2.9 12			1.8 23				-- 2.3				0.2 0.2	

*Location A is above the ANL site.

Location B is below the ANL waste-water outfall.

for unknown alpha activity. As was found during previous years, uranium was the principal contaminant contributed by Argonne waste water. The average uranium concentration, $23 \mu\mu\text{c}/1$, was only 0.3% of the MPC, while the maximum concentration found amounted to about 4% of the MPC. Except for a few samples, uranium analyses were performed on samples collected from both locations on the same day and, therefore, the average results give approximately the uranium contributed by Laboratory waste water on the days of sample collection. The average uranium concentration was higher than the total alpha activity for two reasons. Samples that contained concentrations of total alpha activity above average were usually analyzed for uranium, and the self-absorption corrections used to obtain the total activity from the counting rates are about 15% low for normal uranium.

Some of the below-outfall samples also contained detectable amounts of plutonium, while none was detected in the above-site samples. It can, therefore, be concluded that the plutonium was also added to the stream in Laboratory waste water. The highest plutonium concentration ($25 \mu\mu\text{c}/1$) was only 16% of the MPC, while the average concentration, $2.3 \mu\mu\text{c}/1$, was 1.4% of the MPC. Small amounts of thorium isotopes were found in some of the samples from both locations, but did not contribute greatly to the total activity of the stream. The concentrations ranged from 0.2 to $2.6 \mu\mu\text{c}/1$, and the isotopic composition of the thorium was not investigated. A few of the below-outfall samples probably contained thorium from Argonne waste water.

Monthly summaries of the beta activities in Sawmill Creek water are given in Table XI. Total beta activity below the outfall averaged $45 \mu\mu\text{c}/1$, or $16 \mu\mu\text{c}/1$ higher than above site. However, the magnitude and direction of this difference varied considerably from time to time because of the variable contribution of fallout and ANL waste water to the total beta activity in the stream. The origin of the beta activity found in the stream could usually be determined by comparing 1) samples collected on the same day from both locations, 2) samples collected during periods of high and low fission product activity in air and rainfall, and 3) results of specific fission product and uranium analyses. The average beta activity below the outfall on days when samples from both locations were analyzed was $42 \mu\mu\text{c}/1$, or $13 \mu\mu\text{c}/1$ higher than above the site. Thus, the average increase in the beta activity of the Creek due to Argonne waste water was $13 \mu\mu\text{c}/1$. An approximately equal contribution was made by fallout activity. From July through October higher concentrations of beta activity were often found above the site. This was due to the dilution of high concentrations of fallout activity in Sawmill Creek by Argonne waste water containing smaller concentrations of beta activity. The results of specific fission product analyses also provide evidence for this dilution effect. Fallout activity was also highest in air and rain during this period. However, even during this period, beta activity originating in Argonne waste water could be

TABLE XI
NONVOLATILE BETA RADIOACTIVITIES IN SAWMILL CREEK WATER 1957

Month	Location*	Total Beta Activity		Sr ⁹⁰				Sr ⁸⁹				I ¹³¹				Ce ¹⁴⁴				Ce ¹⁴⁷				Ba ¹⁴⁰			
		No of Samples	μCi/liter	Samples >2μCi/liter				Samples >3μCi/liter				Samples >3μCi/liter				Samples >3μCi/liter				Samples >3μCi/liter							
				No of Samples	μCi/liter			No of Samples	μCi/liter			No of Samples	μCi/liter			No of Samples	μCi/liter			No of Samples	μCi/liter						
					No	Max	Av		No	Max	Av		No	Max	Av		No	Max	Av		No	Max	Av	No	Max	Av	
January	A	1	31.0	--	1	0	--	--	1	1	--	--	1	0	--	--	1	0	--	--	1	0	--	--			
January	B	12	90.3	34.2	3	2	10.8	7.9	3	0	--	--	3	0	--	--	3	1	16.0	--	3	0	--	--			
February	A	4	44.7	30.4	4	--	--	--	4	4	13.5	6.7	4	0	--	--	4	1	13.4	--	4	0	--	--			
February	B	12	165	51	5	3	14.0	7.4	4	2	10.0	8.0	5	4	1.90 x 10 ³	5.87 x 10 ³	5	3	15.0	7.3	5	0	--	--			
March	A	4	17.3	13.2	4	0	--	--	4	3	6.6	4.3	4	0	--	--	4	--	--	--	4	0	--	--			
March	B	13	140	59.3	4	2	34.9	18	4	2	11.0	5.5	23	23	0.10 x 10 ³	1.53 x 10 ³	4	1	10.6	--	4	2	3.0	3.0			
April	A	4	28.4	14.8	4	0	--	--	4	3	11.5	7.4	4	0	--	--	4	0	--	--	4	0	--	--			
April	B	15	173	42	4	3	3.5	7.1	4	1	--	--	4	3	4.0	19.3	4	2	7.2	7.0	4	3	6.9	5.7			
May	A	5	13.1	9.0	5	0	--	--	2	9.8	7.2	5	0	--	--	5	0	--	--	0	--	--	--				
May	B	14	59.6	20.7	1	2.2	--	--	3	9.0	5.9	5	0	--	--	5	0	5.5	4.0	0	10.0	8.3	3	0			
June	A	4	23.1	18.3	4	0	--	--	4	3	13.0	11.0	4	1	4.0	--	4	0	--	--	4	1	12.8	--			
June	B	13	89.8	33.8	4	1	3.3	--	4	--	0	5	4	0	--	--	4	0	--	--	4	0	--	--			
July	A	5	110	66	0	0	--	--	4	1.4	3.3	3	5	4	14	0.0	0	0	--	5	4	7.5	7				
July	B	13	110	4	3	19	2.9	--	0	--	0	0	3	0	--	--	5	1	12.8	--	5	3	30.0	13.1			
August	A	4	69.3	40.1	0	0	--	--	4	4	27	27.6	4	4	37	18.6	3	0	--	--	3	1	4.0	--			
August	B	13	342	72	4	3	17.2	8.4	4	4	9.0	--	4	--	--	--	3	3	10.0	8.4	3	0	--	--			
September	A	4	46	34.2	4	0	--	--	4	4	14	14.5	4	2	4.0	4.6	4	1	18.0	--	4	3	28.0	10.3			
September	B	12	36.0	22.3	4	0	--	--	4	3	9.7	5.1	4	0	--	--	4	1	0	--	4	1	11.4	--			
October	A	5	76.8	40.2	5	0	--	--	0	5	23.0	11.6	5	--	4.5	3.0	4	0	--	--	4	2	16.3	13.4			
October	B	13	285	80	5	0	--	--	5	--	10.4	15.2	5	2	7.6	32.2	4	2	36.7	12.3	4	1	11.0	--			
November	A	4	34.5	10.7	4	0	--	--	4	1	11.0	--	4	0	--	--	2	0	--	--	4	0	--	--			
November	B	11	143	48	4	0	--	--	4	1	3.5	--	4	0	--	--	2	0	--	--	4	0	--	--			
December	A	3	17.0	14.4	4	0	--	--	4	0	--	--	2	0	--	--	0	0	--	--	4	0	--	--			
December	B	12	38.4	26.6	4	2	4.2	3.4	4	1	12.0	--	2	0	--	--	2	0	--	--	4	0	--	--			
Average	A		29			--	--	--		10	1			9	5			9			6		5	3			
	B		45			3	0			4	1			90				3	6			4	1				

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

detected below the outfall from the results of fission product analyses. Sr^{90} was found below the outfall during July and August (as well as during other months), but was never detected in concentrations greater than $2 \mu\mu\text{c}/1$ above site. The Sr^{90} concentration averaged $3.0 \mu\mu\text{c}/1$, or about 4% of the MPC; the maximum Sr^{90} concentrations found was $34.8 \mu\mu\text{c}/1$, or about 43% of the MPC. The longer-lived cerium isotope, 275-d Ce^{144} was also found below the outfall on days when it was not detected above site. Except for Sr^{90} , all the fission products for which analyses were made were added to the stream at various times by both fallout activity and waste water. All results of fission product analyses were corrected for decay to the time of collection of the sample. As indicated in the table, large concentrations of 8.1-d I^{131} were found in below-site water during February and March, and this activity was added to the stream in Laboratory waste water. This was confirmed by the presence of iodine activity in waste water before it was added to the stream, and the absence of radioiodine in above-site water. Approximately equal concentrations of 21-h I^{133} were also found in each sample, indicating that the iodine activities were of recent origin, more recent than found in fallout during the year. This iodine activity originated in a uranium sample undergoing irradiation in the CP-5 reactor and was removed from other fission products by virtue of its volatility. The average I^{131} concentration in below-site water during February and March was equivalent to about 120% of the MPC; the average for the entire year, $880 \mu\mu\text{c}/1$, was about 30% of the MPC. Radioiodine was not observed in the total beta activity, since volatile elements are removed in the preparation of the sample for total beta counting.

Significant amounts of beta activity from the UX_1 and UX_2 daughters of uranium were also found in Creek water below the outfall; this was added in Laboratory waste water. In some samples uranium that had been recently separated from its daughters was found, and the daughter growth was observed. This is additional evidence that below-outfall water contained uranium from Laboratory operations.

Sawmill Creek empties into the Des Plaines River about 500 yards downstream from the waste-water outfall, and the effect of Sawmill Creek water on the radioactivity in the Des Plaines River was determined by sampling the River above and below the mouth of Sawmill Creek at approximately monthly intervals. The results are given in Table XII. The alpha activities and uranium concentrations in water from both locations were low, and no significant or consistent differences between the two locations could be noted. The alpha activities, about $2 \mu\mu\text{c}\alpha/1$ and about $1.4 \mu\mu\text{cU}/1$, were similar to those found during previous years. The beta activities were more variable due to fission product fallout. Increases ranging from 20 to $100 \mu\mu\text{c}/1$ were found during the months of high fallout, July through October. Beta activity due to contamination added to Sawmill Creek could not be detected in any of the

TABLE XII

NONVOLATILE RADIOACTIVITIES IN DES PLAINES RIVER, 1957

Date Collected	Location*	Alpha Activity ($\mu\mu\text{c/liter}$)	Uranium ($\mu\mu\text{c/liter}$)	Beta Activity ($\mu\mu\text{c/liter}$)
January 16	A	1.0	0.7	18.3
January 16	B	1.0	1.0	20.5
February 20	A	3.0	0.6	25.9
February 20	B	1.6	1.1	19.1
March 20	A	1.9	0.7	29.8
March 20	B	1.7	0.8	25.2
April 17	A	1.5	0.9	19.7
April 17	B	1.3	1.2	15.9
May 15	A	1.6	1.4	18.5
May 15	B	0.7	1.2	6.7
June 19	A	1.7	1.1	25.0
June 19	B	1.1	1.4	19.4
June 26	A	1.7	-	18.1
June 27	B	1.0	-	11.5
July 17	A	2.5	1.2	80.8
July 17	B	2.1	0.7	70.7
August 21	A	2.4	2.0	41.0
August 21	B	1.9	1.7	41.0
September 18	A	4.1	2.3	115
September 18	B	1.9	1.4	54.9
October 16	A	1.6	1.7	69.9
October 16	B	1.2	1.3	32.7
November 20	A	2.1	1.4	16.0
November 20	B	1.7	2.0	17.9
December 18	A	3.1	2.2	14.0
December 18	B	3.6	2.5	12.3
Average	A	2.2	1.4	38
	B	1.6	1.4	27

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

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

samples from the River. There is apparently sufficient dilution so that the radioactivity in Sawmill Creek does not contribute significantly to the alpha or beta activity in the Des Plaines River.

2. Other Water

The total activities found in several ponds on the ANL site are summarized in Table XIII. Except for the storage lagoon, the alpha activities were normal, being about $2 \mu\mu\text{c}/1$, and similar to those found in other years. The beta activities in these samples were also affected by fallout, notably in August. A difference in the origin of the beta activity could be deduced from the decay rate. The beta activities in the natural ponds decayed to 10-15 $\mu\mu\text{c}/1$ in six months regardless of the original activity, and the increases above these values were apparently due to fallout. The beta activities in the storage lagoon samples decayed only 15% in six months.

TABLE XIII

NONVOLATILE RADIOACTIVITIES IN PONDS ON ANL SITE, 1957

Month	No. of Samples	Alpha Activity ($\mu\mu\text{c}/1$)		Beta Activity ($\mu\mu\text{c}/1$)	
		Max.	Av.	Max.	Av.
April	3	2.5	2.0	40.0	30.6
June	4	3.0 ¹	1.4 0.8 ²	37.6 ¹	27.7 24.4 ²
August	3	1.6	0.9	74.1	54.1
December	4	6.0 ¹	3.0 1.9 ²	60.9 ¹	27.8 16.5 ²
Average		2.0 1.4 ²		34.0 22.4 ²	

¹Storage lagoon for contaminated waste water.

²Average excluding results for storage lagoon in June and December.

Under very unusual circumstances there is a possibility that Laboratory waste water from some buildings on the site may enter the drinking or domestic water piping systems within the buildings.

Because of this, both types of water from many of the buildings were sampled on the same day. Twenty-one samples were analyzed, and all the results were uniformly low. The alpha activities ranged from 0.2 ± 0.2 to $0.6 \pm 0.3 \mu\mu\text{c}/\text{l}$ and the beta activities ranged from 2.7 ± 0.5 to $6.5 \pm 1.0 \mu\mu\text{c}/\text{l}$. These concentrations are essentially the same as those found in untreated Lake Michigan water.

The total activities in water from lakes and streams near the ANL site are given in Tables XIV and XV. The alpha activities were normal and ranged from 0.2 and $3.9 \mu\mu\text{c}/\text{l}$. As was found previously, the highest alpha activities were generally found in the DuPage River at Naperville and the lowest in Lake Michigan. The average beta activity, about $21 \mu\mu\text{c}/\text{l}$, was similar to that found in most other years. The highest beta activities were found in the October samples as a result of increased fallout. The fallout added an average of about $15 \mu\mu\text{c}/\text{l}$ to the beta activity. An abnormally high concentration of beta activity, $103 \mu\mu\text{c}/\text{l}$, was found in the DuPage River at Channahon in December. The activity decayed rapidly and had decreased to $39 \mu\mu\text{c}/\text{l}$ in two months. All other samples collected near the Laboratory in December contained less than $20 \mu\mu\text{c}/\text{l}$.

There was no correlation between activity and distance from the Laboratory in any of the samples collected near the Laboratory. The Des Plaines River empties into the Illinois River at McKinley Woods, and water was collected at this point, as well as from the Illinois River at Morris and at Starved Rock State Park. No unusual activities were found at any of these locations.

Water was also collected from the Sanitary and Ship Canal near Lemont in November. On November 5, several curies of 85-d Sc^{45} and tritium were added to the Canal by a group from Northwestern University in a tracer experiment. The scandium and tritium activities found in the samples on November 5 were $360 \mu\mu\text{c}/\text{l}$ and $3.3 \times 10^5 \mu\mu\text{c}/\text{l}$, respectively. Neither nuclide could be detected on the following day.

The results obtained for the 100-mile samples are given in Table XVI. The average alpha and beta activities, 0.7 and $16 \mu\mu\text{c}/\text{l}$, respectively, were normal and similar to those found previously. The December samples from Shafer Lake and Pipestone Lake had abnormally high concentrations of beta activity. This was probably due to fallout in those areas, since the samples decayed in three months from 20 to $9 \mu\mu\text{c}/\text{l}$ in the Shafer Lake sample and from 80 to $30 \mu\mu\text{c}/\text{l}$ for the Pipestone Lake sample.

D. Bottom Silt

The results of measurements of total activity on bottom silt from Sawmill Creek and the DesPlaines River are given in Table XVII.

TABLE XIV

NONVOLATILE RADIOACTIVITIES IN LAKES AND STREAMS NEAR ANL, 1957

Lake or Stream	Location	April		June		October		December		Average	
		$\mu\text{C}\alpha/1$	$\mu\text{C}\beta/1$	$\mu\text{C}\alpha/1$	$\mu\text{C}\beta/1$	$\mu\text{C}\alpha/1$	$\mu\text{C}\beta/1$	$\mu\text{C}\alpha/1$	$\mu\text{C}\beta/1$	$\mu\text{C}\alpha/1$	$\mu\text{C}\beta/1$
DesPlaines River ¹	Irving Park Road	2.0	11.5	3.7	30.8	1.6	21.2	1.9	18.6	2.3	20.5
DesPlaines River ¹	Willow Springs	1.5	19.7	1.7	18.1	1.6	69.9	3.1	14.0	2.0	30.4
DesPlaines River ²	Lemont	1.3	15.9	1.0	11.5	1.2	32.7	3.6	12.3	1.8	18.1
DesPlaines River ²	Romeoville	1.8	11.0	1.4	11.1	2.5	40.8	2.2	13.8	2.0	19.2
DesPlaines River ²	Brandon Road, Joliet	--	--	0.5	9.7	--	--	--	--	0.5	9.7
DuPage River	Naperville	3.9	17.2	2.7	24.3	2.2	20.1	3.5	14.2	3.1	19.0
DuPage River	Channahon	2.2	11.4	2.9	10.8	1.5	78.3	2.6	103	2.3	51
Ill. & Mich. Canal	Channahon	1.3	22.5	1.3	11.8	--	--	--	--	1.3	17.2
Fox River	Aurora	--	--	0.5	10.5	--	--	1.3	15.1	0.9	12.8
Flag Creek	Willow Springs	0.7	13.2	1.2	32.5	--	--	--	--	1.0	22.9
Saganaskee Slough	104th Ave. & Sag Canal	1.0	27.8	--	--	0.5	23.6	0.5	18.8	0.7	23.4
Cal-Sag Canal	U.S. Rt. 83 & 86th Ave.	0.6	13.2	--	--	0.5	13.3	--	--	0.6	13.3
Long Run Creek	135th St. & Archer Ave.	1.0	8.0	--	--	1.0	7.9	--	--	1.0	8.0
Sauk Trail Lake	226th St. & Western Ave.	1.2	10.3	--	--	1.0	20.4	--	--	1.1	15.4
Confluence - DesPlaines, Ill., & Kankakee Rivers	McKinley Woods	1.4	9.9	2.2	16.3	0.8	8.9	1.4	10.7	1.5	11.5
Illinois River	Morris	--	--	1.0	8.1	--	--	1.2	7.7	1.1	7.9
San. & Ship Canal	Lemont	--	--	--	--	2.1	35.0	--	--	2.1	35.0
Calumet Lake	111th St., Chicago	--	--	--	--	0.7	25.1	1.1	17.2	0.9	21.2
Lake Michigan	98th St., Chicago	--	--	--	--	0.2	4.3	0.4	6.4	0.3	5.4
McGinnis Slough	U.S. Rt. 45 & Ill. Rt. 7	--	--	--	--	1.1	25.8	--	--	1.1	25.8

¹Above mouth of Sawmill Creek²Below mouth of Sawmill Creek

TABLE XV

NONVOLATILE RADIOACTIVITIES IN LAKES
AND STREAMS NEAR ANL, 1957

Distance From ANL (miles)	Date	No. of Samples	Alpha Activity, $\mu\mu\text{c/liter}$		Beta Activity, $\mu\mu\text{c/liter}$	
			Max.	Av.	Max.	Av.
10	April	7	1.8	1.1	27.8	15.5
10	June	4	1.7	1.3	32.5	18.3
10	October	8	2.5	1.3	69.9	31.1
10	December	4	3.6	2.3	18.8	14.7
10 (average)			1.4		21	
25	April	5	3.9	2.1	17.2	12.1
25	June	8	3.7	1.8	30.8	15.3
25	October	7	2.2	1.1	78.3	25.5
25	December	8	3.5	1.7	103	24.1
25 (average)			1.7		20	
Annual Average			1.5		21	

TABLE XVI

NONVOLATILE RADIOACTIVITIES IN WATER
FROM REFERENCE SITES, 1957

Location	June		December	
	$\mu\mu\alpha/1$	$\mu\mu\beta/1$	$\mu\mu\alpha/1$	$\mu\mu\beta/1$
Lake Geneva, Wisconsin	0.1	5.6	0.2	4.1
Lake Delavan, Wisconsin	1.0	15.6	0.7	12.2
Illinois River, Starved Rock State Park	0.8	10.2	1.3	15.1
Shafer Lake, Monticello, Indiana	0.8	6.7	1.5	28.7
Lake Michigan, St. Joseph, Michigan	0.1	3.7	0.4	4.6
Pipestone Lake, Michigan	0.1	2.6	1.1	80.3
Average	0.5	7.7	0.9	24.2

TABLE XVII

NONVOLATILE RADIOACTIVITIES IN BOTTOM SILT FROM
SAWMILL CREEK AND DES PLAINES RIVER, 1957

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 16	A	-	-	A	16	38
January 16	B	28	48	B	20	59
February 20	A	20	55	A	22	54
February 20	B	28	58	B	25	55
March 20	A	26	51	A	21	61
March 20	B	24	48	B	21	46
April 17	A	22	39	A	20	58
April 17	B	22	37	B	22	38
June 19	A	23	65	A	20	52
June 19	B	46	67	B	29	61
June 26	A	23	65	A	22	69
June 26	B	24	57	B	21	79
July 17	A	26	78	A	25	155
July 17	B	11	35	B	22	49
August 21	A	18	48	A	22	56
August 21	B	61	110	B	21	73
October 2	A	23	58	A	22	85
October 2	B	126	108	B	22	96
October 16	A	26	67	A	-	-
October 16	B	374	364	B	25	60
December 18	A	25	75	A	17	57
December 18	B	398	1157	B	23	87
Average	A	23	60	A	21	69
	B	104	190	B	23	64

¹Location A is above the ANL site.

Location B is below the ANL waste-water outfall.

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

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

Normal values for bottom silt from these two streams range from about 10 to 30 $\mu\mu\alpha/g$ and 50 to 90 $\mu\mu\beta/g$, depending on the nature of the individual sample. Samples from Sawmill Creek above the site throughout the year and from below the outfall from January through July were normal. Increases ranging from 30 to 300 $\mu\mu\alpha/g$ and 20 to 1,000 $\mu\mu\beta/g$ were found in the below-site samples collected from August through December. The increased activities in these below-outfall samples were derived primarily from radioactivity added to the stream in Argonne waste water, although some of the beta activity may have been derived from fallout. This is confirmed by the results given in Table XVIII. Abnormally high concentrations of uranium, plutonium, and strontium-90 were found only in the samples collected below the outfall, and these nuclides were also present in abnormally high concentrations in below-outfall water. The plutonium/uranium ratio in the below-site bottom silt was about 15 times greater than has generally been found in the water from that location. Since the relative concentrations of a particular nuclide in water and bottom silt will depend on many factors, including the chemistry of the element, the nature of the stream bed, and the chemical composition of the water, the concentration in bottom silt can be predicted from the water concentration only if all the variables are correctly evaluated. However, for long-lived nuclides the bottom silt should be a sensitive qualitative index of the activity added to the Creek in waste water over a period of years.

TABLE XVIII
RADIOACTIVITIES IN BOTTOM SILT, 1957

Location	Date Collected	Alpha Activity, $\mu\mu\alpha/g$	Beta Activity, $\mu\mu\beta/g$	Uranium, $\mu g/g$	Plutonium, $\mu\mu c/g$	Thorium, $\mu\mu c/g$	Sr^{90} , $\mu\mu c/g$
Sawmill Creek - below outfall	10-16	374	364	85	93	7	8.4
Sawmill Creek - below outfall	12-18	398	1157	101	149	9	13.5
Sawmill Creek - above site	12-18	25	75	2.8	-	-	< 1.5
Pond on ANL site	4-27	29	116	2.4	< 0.3	3	< 1.5
Des Plaines River - above site	6-26	25	147	2.7	-	-	< 1.5
Des Plaines River - below site	9-24	13	68	2.3	-	-	< 1.5
Des Plaines River - below site	9-25	28	198	2.3	-	-	< 1.5
Des Plaines River - above site	9-25	24	142	2.5	-	-	< 1.5
Du Page River, Naperville	12-17	85	75	4.4	-	-	< 1.5

The relatively high concentration of alpha activity (85 $\mu\mu\alpha/g$) in the sample from the Du Page River is reflected in the uranium concentration. This sample contained 4.4 $\mu gU/g$, while all the other samples analyzed (except from below the outfall) contained from 2.3 to 2.8 $\mu gU/g$. Similar results have been obtained from the Du Page River in previous years. Above-average concentrations of other naturally occurring radioactive nuclides have also been found at this location.

Bottom silt from the Des Plaines River averaged essentially the same above and below the ANL site. The averages, about 22 $\mu\mu\alpha/g$ and 67 $\mu\mu\beta/g$, respectively, were in the range normally found in this

stream. Thus, the contamination added to Sawmill Creek by ANL waste water did not contribute significantly to the radioactivity in Des Plaines River bottom silt. The concentrations of beta emitters increased during the summer when fallout activity increased. The large differences of beta activities in the July samples were probably due to the fact that the above-site samples consisted primarily of clay, while the below-site sample contained a large fraction of sand. It has been generally observed that stream beds consisting of clay contain the largest concentrations of radioactivity, while sand beds contain little activity.

The results of extensive sampling of the beds of Sawmill Creek and the Des Plaines River in September and November are plotted in Figures 11 and 12. The results are consistent with those obtained for the monthly samples. In Sawmill Creek increases in both alpha and beta activities by factors of about three and six, respectively, were found 20, 25, and 200 yards downstream from the waste-water outfall. The Creek bed was not uniformly contaminated, and the amount of contamination was not a function of the distance downstream from the outfall. Large variations in activity with time and location were also observed in bottom silt from all streams, probably as a result of variations in flow rate and in the chemical and physical nature of the stream bed. A study of some of the variables is planned.

The survey of the bed of the Des Plaines River did not show any activity that could be attributed to ANL waste water. It should be noted that increases due to ANL waste water should be observed in both the alpha and beta concentrations, as was found in Sawmill Creek bottom silt. The alpha activities (9 to $28 \mu\mu\text{c/g}$) were in the normal range. The beta activities showed greater variation (25 to $198 \mu\mu\text{c/g}$), presumably due to the varying amounts of fallout. The total beta activities decayed from 20 to 60% in four months. No pronounced trend in activity with distance could be ascertained, although the average activity was slightly higher from 4,200 to 5,500 yards than farther upstream. The physical characteristics of the bed were variable, and, in general, samples consisting largely of clay contained more activity than samples containing a large percentage of sand.

Bottom silts from ponds on the ANL site were normal, except for samples obtained from the storage lagoon for contaminated waste water. The results are summarized in Table XIX. The bottom silts from the natural ponds contained an average of $26 \mu\mu\alpha/\text{g}$ and $66 \mu\mu\beta/\text{g}$. The activities in samples from the storage lagoon were 10 to 30 times greater. The bed of the storage lagoon contains a variety of nuclides adsorbed from the contaminated water stored in the lagoon periodically.

The results obtained for bottom silts collected from lakes and streams near the Laboratory are given in Tables XX and XXI. The range of activities and the average activity were similar to those found in

Figure 11

NONVOLATILE RADIOACTIVITIES IN SAWMILL CREEK BOTTOM SILT

November, 1957

Figure 12

NONVOLATILE RADIOACTIVITIES IN DESPLAINES RIVER BOTTOM SILT

September, 1957

TABLE XIX

NONVOLATILE RADIOACTIVITIES IN BOTTOM
SILT FROM PONDS ON ANL SITE, 1957

Month Collected	No. of Samples	Alpha Activity, $\mu\mu\text{c/g}$		Beta Activity, $\mu\mu\text{c/g}$	
		Max.	Av.	Max.	Av.
April	3	29	28	116	81
June	4	845 ¹	235	1335 ¹	382
			27 ²		65 ²
August	3	28	26	61	55
December	3	361 ¹	162	770(1)	298
			23(2)		63(2)
Average		122	26 ²	218	66 ²

¹Storage lagoon for radioactive waste water.

²Average excluding storage lagoon samples.

previous years. The beta activities in most samples exhibited decay, and the rate of decay was greater for the higher samples. This short-lived activity was presumably due to fallout. The alpha and beta activities in bottom silts from the reference sites (Table XXII) were uniformly low, ranging from 1.5 to 16 $\mu\mu\text{c}\alpha/\text{g}$ and 8 to 37 $\mu\mu\text{c}\beta/\text{g}$. No abnormal results were obtained. The average values (6 $\mu\mu\text{c}\alpha/\text{g}$ and 21 $\mu\mu\text{c}\beta/\text{g}$) were lower than for samples collected near or on the Laboratory site, because the reference site samples were usually sandy and contained very little fission products of recent origin.

E. Soil

The alpha and beta activities found in surface soil on the ANL site during 1957 are summarized in Table XXIII. Most of the samples were in the normal range of 20-30 $\mu\mu\text{c}\alpha/\text{g}$ and 40-80 $\mu\mu\text{c}\beta/\text{g}$. A few of the samples collected in June, August, and October contained 25 to 150 $\mu\mu\text{c}/\text{g}$ more beta activity than normal. These increases, observed only during periods of high fallout, were evidently due to fallout activity. The beta activities in these samples decayed to normal values in about four months, regardless of the original activity, while the alpha activity remained constant. Similar results were observed in samples collected near the Laboratory site during the same periods. One sample collected near a uranium storage shed on the site in December contained 39 $\mu\mu\text{c}\alpha/\text{g}$ and 106 $\mu\mu\text{c}\beta/\text{g}$,

TABLE XX

NONVOLATILE RADIOACTIVITIES IN BOTTOM SILTS FROM LAKES AND STREAMS NEAR ANL, 1957

Lake or Stream	Location	April		June		October		December		Average	
		$\mu\mu\text{ca}/1$	$\mu\mu\text{cb}/1$	$\mu\mu\text{ca}/1$	$\mu\mu\text{cb}/1$	$\mu\mu\text{ca}/1$	$\mu\mu\text{cb}/1$	$\mu\mu\text{ca}/1$	$\mu\mu\text{cb}/1$	$\mu\mu\text{ca}/1$	$\mu\mu\text{cb}/1$
DesPlaines River ¹	Irving Park Road	31	86	25	147	24	143	22	57	26	108
DesPlaines River ¹	Willow Springs	16	38	20	52	-	-	17	57	18	49
DesPlaines River ²	Lemont	20	59	29	61	25	60	23	87	24	67
DesPlaines River ²	Romeoville	29	99	23	73	17	83	24	117	23	93
DesPlaines River ²	Brandon Rd., Joliet	-	-	15	37	-	-	-	-	15	37
DuPage River	Naperville	41	57	12	21	20	33	84	75	39	47
DuPage River	Channahon	30	64	35	66	16	54	9	23	23	52
Ill. & Mich. Canal	Channahon	29	50	20	35	-	-	-	-	25	43
Fox River	Aurora	-	-	21	82	-	-	3	23	12	53
Flag Creek	Willow Springs	27	79	9	25	-	-	-	-	18	52
Saganaskee Slough	104th Ave. & Sag Canal	17	49	-	-	16	65	-	-	17	57
Long Run Creek	135th St. & Archer Ave.	29	72	-	-	21	91	-	-	25	82
Sauk Trail Lake	226th St. & Western Ave.	21	52	-	-	20	53	-	-	21	53
Illinois River	Morris	-	-	12	35	-	-	8	24	10	30
Calumet Lake	111th St., Chicago	-	-	-	-	20	110	21	41	21	76
Lake Michigan	98th St., Chicago	-	-	-	-	3	26	-	-	3	26
McGinnis Slough	U.S. Rt. 45 & Ill. Rt. 7	-	-	-	-	27	89	-	-	27	89

¹Above mouth of Sawmill Creek²Below mouth of Sawmill Creek

TABLE XXI

NONVOLATILE RADIOACTIVITIES IN BOTTOM
SILTS NEAR ANL, 1957

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	7	41	24	99	62
10	June	5	29	23	73	46
10	October	6	27	21	91	70
10	December	4	84	37	117	84
10 (average)			25		65	
25	April	4	31	30	86	68
25	June	6	35	21	147	67
25	October	5	24	17	143	77
25	December	5	22	13	57	34
25 (average)			20		61	
Annual Average			23		63	

TABLE XXII

NONVOLATILE RADIOACTIVITIES IN BOTTOM SILTS
FROM REFERENCE SITES, 1957

Location	June		December	
	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$
Lake Geneva, Wisconsin	3.4	19	-	-
Lake Delavan, Wisconsin	3.4	12	16	37
Illinois River, Starved Rock State Park	4.1	8	-	-
Lake Shafer, Indiana	2.9	23	5.9	28
Lake Michigan, St. Joseph, Michigan	3.6	14	-	-
Pipestone Lake, Michigan	2.2	25	1.5	11
Average	3.3	17	8	25

TABLE XXIII
NONVOLATILE RADIOACTIVITIES IN SURFACE SOIL
ON ANL SITE, 1957

Month Collected	No. of Samples	Alpha Activity, $\mu\mu\text{c}/\text{gram}$		Beta Activity, $\mu\mu\text{c}/\text{gram}$	
		Max.	Av.	Max.	Av.
January	4	27	23	62	57
March	20	31	23	76	62
May	4	30	24	67	58
June	7	33	25	95	70
August	7	29	26	229	101
October	2	21	17	85	67
December	3	39	26	106	76
Annual Summary	47	39	24	229	70

about 20 $\mu\mu\text{c}/\text{g}$ higher than soil obtained 50 yards from the shed. The alpha and beta activities in this sample did not decay. This increase was due to uranium contamination from the shed and has been observed in previous years.

The samples collected in March were obtained from the immediate vicinity of the EBWR building as part of a study of the activity leaving the reactor. Samples were collected 10, 50, 100, 250, and 500 yards from the building in four directions. The alpha and beta activities in all samples were normal, ranging from 18-31 $\mu\mu\text{c}/\text{g}$ and 54-76 $\mu\mu\text{c}/\text{g}$; no trend with direction or distance was noted. The results will be used as a basis for comparison with similar surveys in the future to determine if the reactor is affecting the radioactivity of its environment.

Soil from locations within 25 miles of the Laboratory (Table XXIV) contained an average of 23 and 70 micromicrocuries of alpha and beta activities, respectively. These values were essentially the same as those found on the Laboratory site. The alpha activities were similar to those found in previous years from the same locations, although the beta values averaged about 15 $\mu\mu\text{c}/\text{g}$ higher than in the past three years. The latter increase is attributed to increased fission product activity from fallout in some of the samples. The beta activities in such samples decayed to normal values in about four months. The total activities in soil from the reference sites (Table XXV) were normal and have not changed significantly during the past few years. No appreciable amount of fallout was detected in any of the samples during 1957.

TABLE XXIV

NONVOLATILE RADIOACTIVITY IN SURFACE SOIL
NEAR ANL, 1957

Distance From ANL (miles)	Month Collected	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	5	21	18	67	58
10	June	6	30	23	139	72
10	October	7	26	20	310	95
10	December	3	21	18	70	60
10 (average)			20		75	
25	April	5	29	21	65	59
25	June	6	26	19	77	55
25	October	7	23	21	97	74
25	December	3	36	24	111	76
25 (average)			21		65	
Annual Average			23		70	

TABLE XXV

NONVOLATILE RADIOACTIVITIES IN SURFACE SOIL
AT REFERENCE SITES, 1957

	June		December	
	$\mu\mu\text{c}\alpha/\text{g}$	$\mu\mu\text{c}\beta/\text{g}$	$\mu\mu\text{c}\alpha/\text{g}$	$\mu\mu\text{c}\beta/\text{g}$
Geneva, Wisconsin	19	46	-	-
Delavan, Wisconsin	17	45	15	54
Starved Rock, Illinois	22	37	19	45
Lake Shafer, Indiana	14	46	16	44
St. Joseph, Michigan	11	36	13	52
Pipestone Lake, Michigan	6	31	6	33
Average	15	40	14	46

F. Plants

Plant collection was limited to grass, since it was available at all locations. The results of analysis of total activity of grass during 1957 are summarized in Tables XXVI, XXVII, and XXVIII. Concentrations are given in terms of the oven-dried samples. The alpha activity averaged approximately $1.6 \mu\mu\text{c/g}$ at all locations, and the individual values were in the range normally found. The average beta activities on and near the ANL site were 170 to $132 \mu\mu\text{c/g}$, respectively, or about twice that found in previous years. This increase in the average resulted from the unusually high results in March, August, and October for the on-site samples and in April and October for the off-site samples. For the August and October samples, the increases in beta activity corresponded to increases in air and rain activity; these were evidently due to fallout. The high results for samples collected on the site late in March and near the Laboratory early in April are difficult to explain. The beta activity in air samples increased from about $1.2 \mu\mu\text{c/M}^3$ during the first $2\frac{1}{2}$ months of the year to about $2 \mu\mu\text{c/l}$ during the two weeks prior to the March sample collection. In addition, a heavy rainfall (0.7 in.) on March 19 contained approximately $1500 \mu\mu\text{c/l}$ of beta activity about 30 days old. The fission products in this rain may have been concentrated by the grass to an unusual extent, although in the past this amount of rain-out has not produced beta activity increases of the magnitude found in March and April of this year.

TABLE XXVI

NONVOLATILE RADIOACTIVITIES IN GRASS ON ANL SITE, 1957

Date Collected	No. of Samples	Alpha Activity, $\mu\mu\text{c/g}$		Alpha Activity, $\mu\mu\text{c/g}$	
		Max.	Av.	Max.	Av.
January 28, 29	4	0.9	0.8	106	86
March 28, 29	11	7.4	2.9	293	199
June 28	7	1.1	0.8	128	96
August 7	7	1.1	0.8	394	283
October 2	2	2.7	1.5	191	178
December 26	6	3.6	1.7	76	62
Average		1.6		170	

TABLE XXVII
NONVOLATILE RADIOACTIVITIES IN GRASS
NEAR ANL, 1957

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	6	5.0	2.6	277	182
10	June	6	2.1	1.0	81	73
10	October	6	1.7	0.9	235	178
10	December	3	2.0	1.4	66	58
10 (average)			1.5		132	
25	April	4	4.3	3.6	254	198
25	June	5	0.8	0.6	113	80
25	October	4	1.6	1.0	210	183
25	December	3	2.7	1.6	71	58
25 (average)			1.6		131	
Annual Average			1.6		132	

TABLE XXVIII
NONVOLATILE RADIOACTIVITIES IN GRASS
FROM REFERENCE SITES, 1957

Location	June		December	
	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$	$\mu\mu\alpha/\text{g}$	$\mu\mu\beta/\text{g}$
Geneva, Wisconsin	1.6	56	0.8	43
Delavan, Wisconsin	1.7	72	-	-
Starved Rock, Illinois	1.9	78	4.2	88
Shafer Lake, Monticello, Indiana	0.7	48	-	-
St. Joseph, Michigan	1.9	78	0.5	26
Pipestone Lake, Michigan	0.2	40	-	-
Average	1.3	62	1.8	52

The beta activity in all of the samples, including those collected in March and April, decayed to normal values ($40-80 \mu\mu\text{c/g}$), regardless of the initial activity, with the most active samples decaying at the highest rates.

G. Animals

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

Two fish samples were collected from the ponds on the ANL site in September. A group of several bullheads contained $0.1 \mu\mu\text{c}\alpha/\text{g}$ and $9.6 \mu\mu\text{c}\beta/\text{g}$ and a sample of bluegills contained $0.1 \mu\mu\text{c}\alpha/\text{g}$ and $12.3 \mu\mu\text{c}\beta/\text{g}$. These results were similar to the total activities found in fish from the same ponds in previous years. Earlier results ranged from 0.2 to $1.7 \mu\mu\text{c}\alpha/\text{g}$ and 16 to $23 \mu\mu\text{c}\beta/\text{g}$.

An aged deer, from a herd that lives on the ANL site, was obtained in May and several organs were analyzed for total activity. Samples of leg bone, leg muscle, lung, liver, kidney, and spleen were counted. The alpha activities ranged from $0.2 \mu\mu\text{c/g}$ in the spleen to $2.1 \mu\mu\text{c/g}$ in the bone; the beta activities ranged from $2.0 \mu\mu\text{c/g}$ in the kidney to $8.3 \mu\mu\text{c/g}$ in the spleen. The results were considered to be normal. All animal results are given in terms of the air-dried samples.