408014

NYO-4889

A STUDY OF FALLOUT IN RAINFALL COLLECTIONS FROM MARCH THROUGH JULY 1956

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and

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April 30, 1957

A study of total β activity and radiostrontium in rain water was undertaken at HASL during the spring of 1956. At that time a survey of atmospheric aerosols and the elemental constituents of rainfall was being conducted by the Cloud Physics section of the Air Force Cambridge Research Center. The samples from the network of stations were analyzed by a contractor, Skinner and Sherman, of Boston, Massachusetts. HASL received a part of the total month's sample from each site, if there was sufficient sample for both laboratories to run analyses.

Sampling covered the period from March through July 1956 for 61 stations within the continental United States, Bermuda, Newfoundland, and the Azores. The original purpose of the study at HASL was to correlate the amount of fallout in rainfall with the estimate of total fallout from gummed film measurements.

PROCEDURES

Collection. The rain collection devices consisted of one-liter polyethylene bottles equipped with wide-mouthed funnels that presented a surface area of 0.56 square feet to the atmosphere. The whole assembly was enclosed in a wooden container designed to be opened manually during rain and closed at other times. Figure 1 is a photograph of this apparatus as it was used in the field.(1)

Analysis. When each sample was received at HASL the volume was measured and the solution acidified.(2) Then the sample was evaporated to a small volume, transferred to a glass planchet and dried for beta counting. This residue was fused with sodium carbonate and the strontium

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separated with fuming nitric acid. The sample was then stored to allow the Sr^{90} to equilibrate with its yttrium daughter. At this stage the yttrium was separated and precipitated as the oxalate for beta counting.

Sr^{90} was determined from the counting rate of Y^{90}, and Sr^{89} by counting total strontium and subtracting the Sr^{90} result.

Reporting. Sr^{90} and total β activity are reported in units of $mc/mi^2/mo$. These values were calculated from the original counting data (d/m/aliquot) using the formula,

$$mc/mi^2/mo = \frac{d/m/aliquot}{\text{Projected area of funnel } (ft^2)} \times \frac{\text{Total sample volume}}{\text{Aliquot volume}} \times \frac{1}{79.6}$$

For the purpose of these calculations "Total sample volume" refers to the volume of the month's rainfall computed from official U. S. Weather Bureau data.(3)

The Sr^{89} values were obtained in the same way but for convenience of comparison, were extrapolated to the first day of each sampling month before calculating the $Sr^{89/90}$ ratios.

FINDINGS

The data are completely summarized in Table 1. Total β activity, Sr^{90} and $Sr^{89/90}$ ratios and rainfall volumes are listed by station for each sampling month. Total β activity is reported as of the counting date because the assignment of a specific burst date is not possible.

Table 1a. Fallout data for March 1956 rain water collections.

HASL #	Site #	Sampling Site	Total β Activity* (mc/mi^2/mo)	Sr^{90} (mc/mi^2/mo)	Sr^{89}/Sr^{90} **
3616	1	West Newton, Mass.	19 ± 1.8	1.2 ± 0.14	14
3617	1	West Newton, Mass.	16 ± 1.8	0.92 ± 0.14	18
3619	7	Hatteras, N. C.	10 ± 0.1	0.83 ± 0.08	22
3620	8	Charleston, S. C.	19 ± 3.0	0.45 ± 0.19	36
3621	11	Tallahassee, Fla.	12 ± 0.9	0.43 ± 0.08	19
3622	12	Mobile, Ala.	50 ± 3.8	2.4 ± 0.26	20
3623	13	Jackson, Miss.	20 ± 1.9	1.6 ± 0.16	15
3624	14	Montgomery, Ala.	25 ± 0.3	1.6 ± 0.16	21
3625	15	Lake Charles, La.	16 ± 1.2	1.2 ± 0.11	15
3626	17	Nashville, Tenn.	10 ± 1.1	0.82 ± 0.10	21
3627	22	Salem, Ore.	54 ± 2.8	1.7 ± 0.23	66
3628	24	Jacksonville, Fla.	5.9 ± 1.6	0.25 ± 0.11	20
3629	25	Burlington, Vt.	6.6 ± 0.7	0.51 ± 0.07	12
3630	26	Nantucket, Mass.	28 ± 2.3	2.9 ± 0.20	7.3
3631	28	Albany, N. Y.	17 ± 1.6	1.1 ± 0.13	9.3
3632	30	Akron, Ohio	21 ± 1.8	1.6 ± 0.24	22
3633	45	Washington, D. C.	33 ± 1.6	1.1 ± 0.11	20
3634	63	Tatoosh Island, Wash.	33 ± 3.0	1.5 ± 0.23	31

* Total β Activity Counting Date: June 5, 1956.
** Sr^{89} extrapolated to first day of sampling month.

Table 1b. Fallout data for April 1956 rain water collections.

HASL #	Site #	Sampling Site	Total β Activity* ($mc/mi^2/mo$)	Sr^{90} ($mc/mi^2/mo$)	Sr^{89}/Sr^{90} **
3670	1	West Newton, Mass.	26 ± 1.9	1.3 ± 0.15	16
3671	1	West Newton, Mass.	32 ± 1.5	1.3 ± 0.09	9.7
3672	3	Little Rock, Ark.	18 ± 4.4	1.9 ± 0.38	0
3673	4	Tampa, Fla.	10 ± 1.4	0.34 ± 0.10	9.9
3674	5	Bermuda	18 ± 1.4	0.45 ± 0.11	11
3676	7	Hatteras, N. C.	80 ± 4.9	1.6 ± 0.33	9.0
3677	8	Charleston, S. C.	60 ± 1.9	0.75 ± 0.11	12
3678	9	Greenville, S. C.	140 ± 3.5	1.9 ± 0.16	9.5
3679	10	West Palm Beach, Fla.	11 ± 1.2	0.34 ± 0.09	15
3680	11	Tallahassee, Fla.	17 ± 1.0	0.58 ± 0.08	6.3
3681	12	Mobile, Ala.	22 ± 2.0	0.52 ± 0.13	10
3682	13	Jackson, Miss.	19 ± 1.5	1.3 ± 0.15	3.5
3683	14	Montgomery, Ala.	14 ± 1.4	0.82 ± 0.16	6.0
3684	16	Brownsville, Texas	25 ± 1.9	2.0 ± 0.20	14
3685	17	Nashville, Tenn.	20 ± 4.1	1.2 ± 0.53	11
3686	19	San Diego, Cal.	19 ± 1.4	0.54 ± 0.14	5.6
3687	20	Santa Maria, Cal.	6.9 ± 0.4	0.26 ± 0.04	5.9
3688	21	Red Bluff, Cal.	12 ± 0.9	0.85 ± 0.09	9.5
3689	24	Jacksonville, Fla.	17 ± 0.8	0.69 ± 0.08	8.5
3690	25	Burlington, Vt.	42 ± 1.2	0.79 ± 0.08	4.9
3691	26	Nantucket, Mass.	14 ± 1.0	0.60 ± 0.09	27
3692	27	Caribou, Me.	17 ± 1.0	0.72 ± 0.10	4.6
3693	28	Albany, N. Y.	64 ± 2.4	2.2 ± 0.18	4.8
3694	29	Montoursville, Pa.	82 ± 2.5	1.4 ± 0.15	16
3695	30	Akron, Ohio	74 ± 1.8	1.5 ± 0.13	11
3696	31	Indianapolis, Ind.	31 ± 1.8	1.4 ± 0.16	8.7
3697	32	Madison, Wis.	75 ± 2.7	1.8 ± 0.20	7.5
3698	33	International Falls, Minn.	3.1 ± 0.2	.08 ± 0.02	6.3
3699	34	St. Cloud, Minn.	140 ± 4.1	1.7 ± 0.22	12
3700	35	Sault Ste. Marie, Mich.	57 ± 1.9	0.98 ± 0.12	0
3701	36	Des Moines, Iowa	55 ± 2.6	0.67 ± 0.23	23
3702	37	Columbia, Mo.	27 ± 1.4	0.83 ± 0.12	7.3
3703	38	Ft. Worth, Texas	30 ± 1.2	0.99 ± 0.10	8.9
3704	39	San Angelo, Texas	30 ± 0.2	1.0 ± 0.16	12
3705	42	Wichita, Kan.	27 ± 1.6	0.34 ± 0.14	22
3706	44	Grand Island, Neb.	140 ± 3.8	2.9 ± 0.21	7.3
3707	45	Washington, D. C.	40 ± 1.2	1.2 ± 0.09	11
3708	46	Huron, S. D.	14 ± 1.6	0.67 ± 0.14	6.4
3709	50	Sheridan, Wyo.	52 ± 2.3	1.6 ± 0.15	8.0
3710	56	Winnemucca, Nev.	31 ± 2.3	0.90 ± 0.19	0
3711	58	Boise, Idaho	26 ± 1.5	0.72 ± 0.11	12
3712	59	Fresno, Cal.	39 ± 1.4		
3713	60	Roanoke, Va.	33 ± 1.5	1.1 ± 0.12	9.3
3714	61	Scottsbluff, Neb.	17 ± 0.2		
3715	64	Grand Rapids, Mich.	31 ± 1.4	1.4 ± 0.14	7.0
3716	66	Stephenville, Newf.	60 ± 2.0	1.7 ± 0.15	18
3717	67	Laredo, Texas	10 ± 1.2	0.66 ± 0.15	7.7

* Total β Activity Counting Date: June 19, 1956.
** Sr^{89} extrapolated to first day of sampling month.

Table 1c. Fallout data for May 1956 rain water collections.

HASL #	Site #	Sampling Site	Total β Activity* ($mc/mi^2/mo$)	Sr^{90} ($mc/mi^2/mo$)	Sr^{89} ** / Sr^{90}
3834	1	West Newton, Mass.	22 ± 2.5	0.55 ± 0.023	33
3835	1	West Newton, Mass.	13 ± 1.3	1.2 ± 0.19	0
3836	2	Medford, Ore.	21 ± 2.3	3.4 ± 0.28	9.6
3837	4	Tampa, Fla.	4.4 ± 1.9	0.21 ± 0.18	0
3838	6	Azores	110 ± 34	10.0 ± 3.8	11
3839	7	Hatteras, N. C.	4.3 ± 1.2	0.77 ± 0.15	0.96
3840	8	Charleston, S. C.	5.6 ± 1.1	0.85 ± 0.13	0
3841	9	Greenville, S. C.	7.7 ± 0.9	0.86 ± 0.11	2.0
3842	10	West Palm Beach, Fla.	23 ± 1.1	1.1 ± 0.11	58
3843	11	Tallahassee, Fla.	8.1 ± 1.4	1.4 ± 0.23	6.9
3845	15	Lake Charles, La.	11 ± 1.1	1.1 ± 0.21	0.6
3846	17	Nashville, Tenn.	5.2 ± 1.6	0.63 ± 0.20	2.9
3847	21	Red Bluff, Cal.	17 ± 1.1	1.4 ± 0.18	0
3848	24	Jacksonville, Fla.	20 ± 1.2	1.0 ± 0.17	14
3849	25	Burlington, Vt.	14 ± 1.4	0.81 ± 0.17	17
3850	26	Nantucket, Mass.	23 ± 1.2	1.5 ± 0.17	6.6
3851	27	Caribou, Me.	9.0 ± 0.6	1.1 ± 0.12	5.7
3852	28	Albany, N. Y.	22 ± 1.0	1.1 ± 0.12	11
3853	29	Montoursville, Pa.	16 ± 1.1	1.1 ± 0.13	9.5
3854	30	Akron, Ohio	39 ± 3.9	2.4 ± 0.57	10
3855	31	Indianapolis, Ind.	19 ± 2.4	1.8 ± 0.30	18
3856	32	Madison, Wis.	28 ± 3.8	3.1 ± 0.56	5.0
3857	44	Grand Island, Neb.	8.1 ± 0.7	0.56 ± 0.095	18
3858	47	Bismark, N. D.	13 ± 1.6	1.2 ± 0.17	8.5
3859	59	Fresno, Cal.	25 ± 1.1	1.1 ± 0.17	5.2
3860	60	Roanoke, Va.	13 ± 1.6	0.59 ± 0.17	21
3861	61	Scottsbluff, Neb.	15 ± 2.8	1.5 ± 0.35	11
3862	62	Yakima, Wash.	5.4 ± 0.62	0.52 ± 0.10	0
3863	63	Tatoosh Island, Wash.	7.6 ± 0.80	0.49 ± 0.099	2.9
3864	66	Stephenville, Newf.	28 ± 1.3	1.9 ± 0.18	9.0
3865	67	Laredo, Texas	17 ± 2.3	5.1 ± 0.38	0

* Total β Activity Counting Date: August 23, 1956.
** Sr^{89} extrapolated to first day of sampling month.

Table 1d. Fallout data for June 1956 rain water collections.

HASL #	Site #	Sampling Site	Total β Activity* ($mc/mi^2/mo$)	Sr^{90} ($mc/mi^2/mo$)	Sr^{89}/Sr^{90} **
3866	1	West Newton, Mass.	12 ± 1.3	1.4 ± 0.20	0
3867	1	West Newton, Mass.	13 ± 2.1	0.47 ± 0.26	0
3868	2	Medford, Ore.	7.6 ± 0.6	0.22 ± 0.09	22
3869	3	Little Rock, Ark.	8.2 ± 5.0	3.6 ± 0.85	1.9
3870	4	Tampa, Fla.	8.3 ± 2.1	0.50 ± 0.21	9.9
3871	5	Bermuda	1.8 ± 1.2	0.65 ± 0.15	0
3872	7	Hatteras, N. C.	15 ± 1.4	0.99 ± 0.20	15
3873	8	Charleston, S. C.	18 ± 1.8	1.6 ± 0.24	0.27
3874	9	Greenville, S. C.	14 ± 1.1	1.1 ± 0.19	1.6
3875	10	West Palm Beach, Fla.	7.9 ± 1.4	0.28 ± 0.16	2.6
3876	11	Tallahassee, Fla.	16 ± 1.8	1.5 ± 0.26	3.2
3877	13	Jackson, Miss.	13 ± 1.6	0.73 ± 0.24	20
3878	14	Montgomery, Ala.	12 ± 1.0	0.66 ± 0.15	14
3879	15	Lake Charles, La.	12 ± 1.4	0.77 ± 0.16	6.5
3880	16	Brownsville, Texas	12 ± 2.5	0.99 ± 0.40	0
3881	24	Jacksonville, Fla.	30 ± 2.3	0.55 ± 0.26	19
3882	26	Nantucket, Mass.	10 ± 1.0	0.50 ± 0.14	1.6
3883	27	Caribou, Me.	35 ± 1.2	2.2 ± 0.18	5.9
3884	28	Albany, N. Y.	21 ± 1.1	0.91 ± 0.15	4.1
3885	29	Montoursville, Pa.	31 ± 2.3	0.73 ± 0.23	0
3886	31	Indianapolis, Ind.	18 ± 2.4	1.7 ± 0.31	0
3887	32	Madison, Wis.	22 ± 1.5	0.74 ± 0.21	13
3888	33	International Falls, Minn.	8.7 ± 1.1	0.68 ± 0.12	3.5
3889	34	St. Cloud, Minn.	38 ± 2.4	2.0 ± 0.27	8.6
3890	35	Sault Ste. Marie, Mich.	32 ± 2.1	1.7 ± 0.29	0
3891	36	Des Moines, Iowa	20 ± 1.4	0.44 ± 0.15	13
3892	37	Columbia, Mo.	13 ± 1.4	0.56 ± 0.21	11
3893	40	Amarillo, Texas	18 ± 1.4	0.94 ± 0.24	10
3895	43	Goodland, Kan.	6.1 ± 1.0	0.76 ± 0.16	6.6
3896	44	Grand Island, Neb.	78 ± 3.2	3.1 ± 0.40	2.0
3897	45	Washington, D. C.	13 ± 0.9	0.44 ± 0.12	7.3
3898	46	Huron, S. D.	11 ± 1.8	0.75 ± 0.20	6.2
3899	47	Bismark, N. D.	20 ± 1.6	0.68 ± 0.25	13
3900	48	Helena, Mont.	61 ± 2.1	1.8 ± 0.19	5.5
3901	49	Glascow, Mont.	14 ± 1.5	1.1 ± 0.18	0
3902	50	Sheridan, Wyo.	12 ± 1.1	0.73 ± 0.16	4.1
3903	57	Spokane, Wash.	16 ± 0.9	0.92 ± 0.12	11
3904	58	Boise, Idaho	7.3 ± 1.2	0.63 ± 0.13	0.43
3905	60	Roanoke, Va.	17 ± 1.2	0.93 ± 0.16	0
3906	62	Yakima, Wash.	35 ± 1.9	0.65 ± 0.23	15
3907	63	Tatoosh Island, Wash.	71 ± 3.0	0.48 ± 0.16	16
3908	64	Grand Rapids, Mich.	19 ± 2.9	0.64 ± 0.35	18
3909	66	Stephenville, Newf.	30 ± 1.3	1.0 ± 0.12	7.8

* Total β Activity Counting Date: August 23, 1956.
** Sr^{89} extrapolated to first day of sampling month.

Table 1e. Fallout data for July 1956 rain water collections.

HASL #	Site #	Sampling Site	Total β Activity* ($mc/mi^2/mo$)	Sr^{90} ($mc/mi^2/mo$)	Sr^{89}/Sr^{90} **
4218	1	West Newton, Mass.	16 ± 1.3	0.59 ± 0.23	20
4219	1	West Newton, Mass.	14 ± 2.5	3.6 ± 0.31	0
4220	4	Tampa, Fla.	50 ± 2.0	1.2 ± 0.14	36
4221	5	Bermuda	29 ± 2.3	2.3 ± 0.34	7.3
4222	8	Charleston, S. C.	34 ± 3.8	1.0 ± 0.28	34
4223	9	Greenville, S. C.	37 ± 3.6	3.1 ± 0.34	1.8
4224	10	West Palm Beach, Fla.	27 ± 4.1	≤ 0.47	
4225	11	Tallahassee, Fla.	120 ± 4.4	1.7 ± 0.29	61
4226	12	Mobile, Ala.	120 ± 4.6	2.5 ± 0.33	64
4227	14	Montgomery, Ala.	57 ± 3.9	9.6 ± 0.67	5.5
4228	18	Tucson, Ariz.	59 ± 6.7	2.1 ± 0.48	35
4229	24	Jacksonville, Fla.	68 ± 3.1	1.6 ± 0.26	52
4230	25	Burlington, Vt.	12 ± 2.1	1.3 ± 0.33	11
4231	26	Nantucket, Mass.	11 ± 1.8	0.52 ± 0.15	25
4232	27	Caribou, Me.	28 ± 2.0	0.92 ± 0.16	15
4233	28	Albany, N.Y.	25 ± 2.4	0.88 ± 0.31	2.1
4234	29	Montoursville, Pa.	22 ± 3.1	1.7 ± 0.29	5.8
4235	30	Akron, Ohio	65 ± 6.8	1.9 ± 0.54	50
4236	31	Indianapolis, Ind.	56 ± 2.4	0.83 ± 0.21	42
4237	32	Madison, Wis.	19 ± 2.1	0.89 ± 0.19	19
4238	34	St. Cloud, Minn.	33 ± 3.0	0.84 ± 0.15	33
4239	36	Des Moines, Iowa	38 ± 1.8	1.1 ± 0.14	30
4240	37	Columbia, Mo.	110 ± 3.4	1.4 ± 0.31	41
4241	40	Amarillo, Texas	170 ± 5.4	2.4 ± 0.36	58
4242	42	Wichita, Kan.	40 ± 3.3	0.62 ± 0.30	67
4243	43	Goodland, Kan.	74 ± 4.0	0.91 ± 0.53	41
4244	45	Washington, D. C.	47 ± 2.0	1.4 ± 0.20	30
4245	46	Huron, S. D.	19 ± 1.6	0.77 ± 0.19	32
4246	47	Bismark, N. D.	24 ± 2.1	0.74 ± 0.33	25
4247	48	Helena, Mont.	21 ± 1.5	0.90 ± 0.18	34
4248	49	Glascow, Mont.	6.3 ± 1.8	0.53 ± 0.26	0
4249	51	Albuquerque, N. M.	22 ± 1.6	0.69 ± 0.23	24
4250	54	Las Vegas, Nev.	54 ± 2.4	0.78 ± 0.16	40
4251	61	Scottsbluff, Neb.	18 ± 1.2	0.24 ± 0.14	37
4217	66	Stephenville, Newf.	7.7 ± 1.2	0.63 ± 0.12	4.4

* Total β Activity Counting Date: October 4, 1956.
** Sr^{89} extrapolated to first day of sampling month.

Table 1f. Comparison of Air Force (AF) and Weather Bureau (WB) Rainfall Data.

Site #	Sampling Site	Inches of Rain									
		March 1956		April 1956		May 1956		June 1956		July 1956	
		W.B.	A.F.	W.B.	A.F.	W.B.	A.F.	W.B.	A.F.	W.B.	A.F.
1	West Newton, Mass.	5.46	4.44	2.57	2.35	1.90	1.07	1.56	1.14	3.54	1.81
1	West Newton, Mass.	5.46	4.18	2.57	2.23	1.90	1.07	1.56	1.16	3.54	1.91
2	Medford, Ore.					4.18	1.18	0.80	0.80		
3	Little Rock, Ark.			4.64	1.47			5.08	0.97		
4	Tampa, Fla.			2.08	1.37	2.15	1.25	2.86	1.30	3.69	3.11
5	Bermuda			1.48	1.34			1.41	1.18	5.09	4.54
6	Azores					22.0	0.97				
7	Hatteras, N. C.	2.80	2.52	3.54	0.76	2.04	1.34	5.51	4.17		
8	Charleston, S. C.	2.45	1.43	2.39	1.45	4.62	2.87	7.69	4.12	10.6	3.01
9	Greenville, S. C.			6.57	3.70	3.88	2.10	2.44	1.61	8.14	4.18
10	West Palm Beach, Fla.			1.26	0.76	3.39	2.69	1.94	1.24	2.98	1.34
11	Tallahassee, Fla.	2.00	1.83	1.90	1.83	5.71	2.73	7.32	4.58	9.78	6.07
12	Mobile, Ala.	9.74	2.29	2.15	1.53					1.01	2.98
13	Jackson, Miss.	6.52	3.24	4.67	2.29			7.37	2.63		
14	Montgomery, Ala.	8.69	5.72	2.03	1.83			3.69	2.37	8.92	3.78
15	Lake Charles, La.	4.38	2.59			5.17	3.59	1.78	1.30		
16	Brownsville, Texas			4.75	2.00			4.02	1.49		
17	Nashville, Tenn.	4.08	3.40	4.23	1.53	2.87	1.57				
18	Tucson, Ariz.									2.70	0.90
19	San Diego, Cal.			1.56	0.99						
20	Santa Maria, Cal.			0.80	1.58						
21	Red Bluff, Cal.			1.27	1.18	4.04	3.43				
22	Salem, Ore.	5.91	4.31								
24	Jacksonville, Fla.	0.81	0.29	2.33	2.10	3.98	3.63	7.87	4.06	8.25	3.62
25	Burlington, Vt.	2.37	1.95	2.47	1.95	4.74	3.74			4.06	1.70
26	Nantucket, Mass.	6.53	3.99	2.26	1.95	3.46	2.94	2.29	1.53	2.75	1.68
27	Caribou, Me.			2.37	1.83	2.42	2.21	3.35	2.71	2.86	1.53
28	Albany, N. Y.	4.76	2.29	2.64	1.11	3.08	2.23	1.83	1.53	2.76	1.32
29	Montoursville, Pa.			3.08	1.53	3.33	2.25	3.02	1.47	7.17	2.29
30	Akron, Ohio	4.23	1.95	3.51	2.14	9.60	1.85			5.12	0.92
31	Indianapolis, Ind.			4.50	2.14	4.96	1.63	3.48	1.53	3.93	2.06
32	Madison, Wis.			3.54	1.07	5.11	2.52	3.24	1.35	4.50	1.75
33	International Falls, Minn.			0.24	0.90			1.06	1.21		
34	St. Cloud, Minn.			2.01	1.14			5.46	2.21	4.79	3.11
35	Sault Ste. Marie, Mich.			1.70	1.41			4.22	2.01	2.76	2.54
36	Des Moines, Iowa			1.24	0.76			1.29	0.95		
37	Columbia, Mo.			2.25	1.85			1.98	1.65	6.75	4.31
38	Fort Worth, Texas			3.12	2.75						
39	San Angelo, Texas			1.44	1.03						
40	Amarillo, Texas							2.03	1.61	2.82	1.11
42	Wichita, Kan.			1.46	0.99					2.51	1.28
43	Goodland, Kan.							0.59	0.93	1.93	0.93
44	Grand Island, Neb.			1.96	1.03	2.43	2.25	3.51	1.53		
45	Washington, D. C.	3.69	2.48	2.25	2.10			2.12	3.23	5.82	4.31
46	Huron, S. D.			1.23	1.79			2.11	0.86	3.47	1.56
47	Bismark, N. D.					3.83	1.81	2.36	1.53	2.78	1.34
48	Helena, Mont.							1.80	1.60	1.04	0.86
49	Glascow, Mont.							1.68	1.30	1.62	0.90
50	Sheridan, Wyo.			1.91	1.53			1.07	0.92		
51	Albuquerque, N. M.									1.49	1.05
54	Las Vegas, Nev.									1.64	1.03
56	Winnemucca, Nev.			0.78	1.76						
57	Spokane, Wash.							1.18	1.26		
58	Boise, Idaho			1.62	1.51			0.80	0.77		
59	Fresno, Cal.			1.38	1.26	0.81	0.69				
60	Roanoke, Va.			3.12	1.72	1.58	1.07	1.72	1.46		
61	Scottsbluff, Neb.			1.54	0.95	2.75	0.76			2.08	1.26
62	Yakima, Wash.					0.48	0.78	1.81	1.03		
63	Tatoosh Island, Wash.	9.88	8.39			1.07	0.89	6.35	4.58		
64	Grand Rapids, Mich.			4.39	2.29			3.36	1.18		
66	Stephenville, Newf.			1.57	0.92	4.34	3.62	3.21	2.29	2.08	1.51
67	Laredo, Texas			1.62	1.16	3.80	1.53				

For March, 17 stations are reported; for April, 47; for May, 31; for June, 43; for July, 35. It will be noted that only six locations submitted enough sample for HASL to receive aliquots for all five months. These were West Newton[4], Charleston, Tallahassee, Jacksonville, Nantucket, and Albany.

Averaged data and ranges for each month are shown in Table 2.

Table 2. Summary of fallout data for rain water collections from March through July, 1956.

Sampling Month	Total β Activity ($mc/mi^2/mo$) Average	Range	Sr^{90} ($mc/mi^2/mo$) Average	Range	$Sr^{89}/90$ Average	Range
March	22	5.9 - 54	1.2	0.25 - 2.9	22	7.3 - 66
April	39	3.1 - 140	1.1	0.34 - 2.9	9.7	0.0 - 23
May	19	4.3 - 110	1.6	0.21 - 3.4	9.3	0.0 - 33
June	20	6.1 - 78	1.0	0.22 - 3.6	7.0	0.0 - 22
July	44	6.3 - 170	1.5	0.24 - 3.6	29	0.0 - 67

DISCUSSION

The data presents several possible modes of analysis. Fallout debris in rain water can be dated; its activity can be correlated with the amount of rainfall; the relationship between total fallout and rain water activity can be established. It is impossible to predict that there will be correlation between activity and amount of rainfall over the entire sampling network because the amount of activity in the atmosphere is not necessarily constant, but varies with local conditions. However, it is possible that better correlation might be found by investigating a fraction of the sampling network over which conditions are more likely to be uniform, The age of fallout can be estimated in two ways, one from the $Sr^{89}/90$ ratio, which varies as a function of time after burst, and the other from percent contribution of Sr^{90} to total β activity. The theoretical $Sr^{89}/90$ ratios used to calculate burst dates were obtained from the Hunter and Ballou yield data for these isotopes and their most recently reported half-life values.(5) The expected percent Sr^{90} in total β activity as a function of time was obtained in the same way. The approximate burst times have been calculated for all the data, and the average burst months for each month's samples, as obtained by both methods are listed in Table 3.

Table 3. Estimated burst dates of fallout in rain water.

Sampling Month	Burst month calculated from average $Sr^{89}/90$ ratios	Burst month calculated from average % Sr^{90}
March	September 1955	March 1954
April	August 1955	November 1954
May	September 1955	November 1951
June	October 1955	February 1954
July	February 1956	October 1954

From this it can be seen that the Sr^{90} contribution to total β activity is high, indicating old debris. At the same time, the $Sr^{89}/90$ ratio is large enough for a much later burst date to be realized. This is possibly due to enrichment of the Sr^{90} in fallout that would occur in a mixture of material from different test series.

Therefore, the $Sr^{89}/90$ ratio is the more sensitive indicator of the age of fallout and can be expected to yield a more valid estimation of relative freshness than the percent Sr^{90}. It is apparent, then, that July rainout is of more recent origin than any of the preceeding months.

It has been hypothesized that fallout material which is entering the troposphere from the stratosphere has a selective entrance zone near the mid-latitude region. If the fallout material is old and originated from a high yield device, it is probable that the debris is stratospheric and upon entrance into the troposphere can be brought down in rainfall. It follows that there would be more activity in rain occurring near the mid-latitudes.

Scatter diagrams of Sr^{90} activity versus inches of rainfall for all months are plotted in figure 2. All values, regardless of location, are plotted but stations below 40° N (an arbitrary limit) appear as black dots on the plots. It is visually apparent from the scatter of the points that there is little correlation on an overall basis. Considering a separation of the data at 40° N, there is better correlation found among southern stations. The specific activity (mc/mi^2/in) of rain water for these stations is generally lower than for northern sites for the duration of the sampling, and the specific activity at each site does not vary considerably from month to month.

Since it has been possible to obtain better correlation by using the 40° N separation, this idea is expanded by considering even smaller areas. For this purpose, four areas in different parts of the sampling network were chosen on the basis of uniformity of specific activity throughout the sampling period. These areas represent the northeast, northwest, southeast, and the southwest sections of the continental United States. The data for each of these areas is plotted in figure 3.

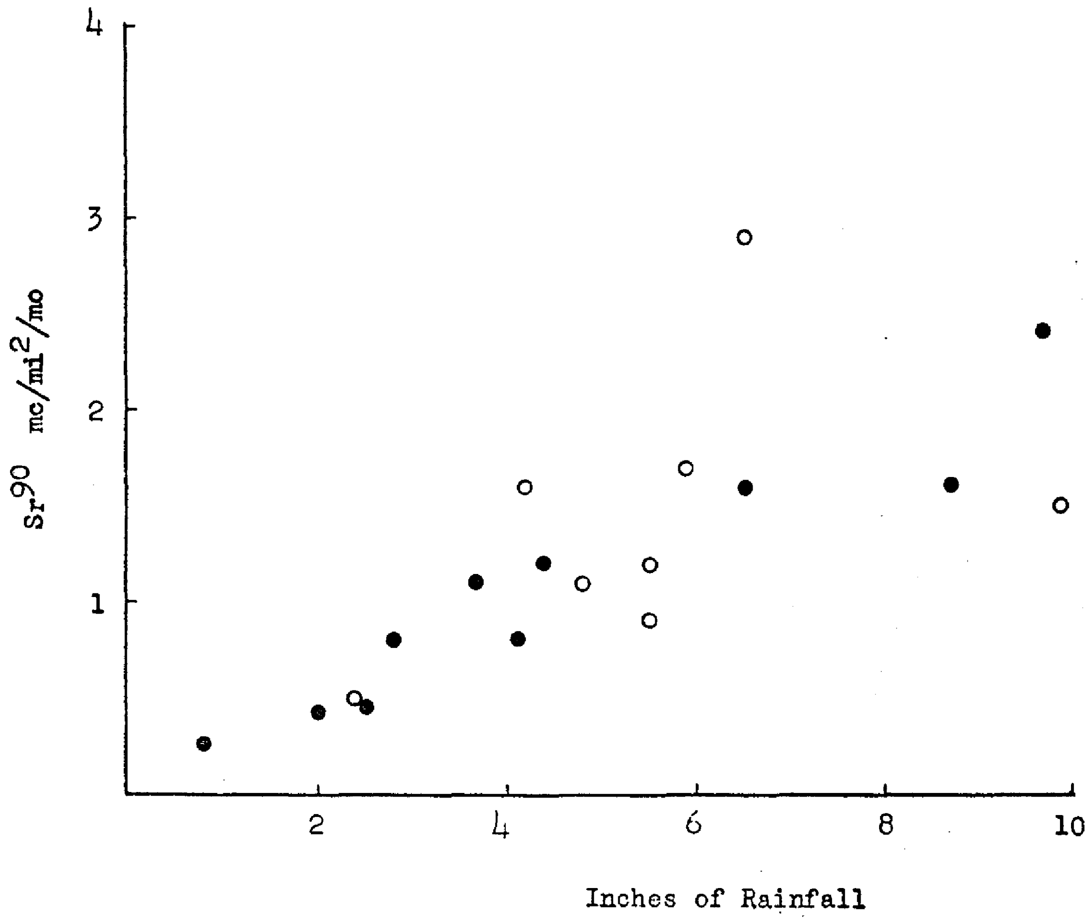

Figure 2a. Regression of Sr^{90} in rain water on the amount of rainfall in March, 1956.

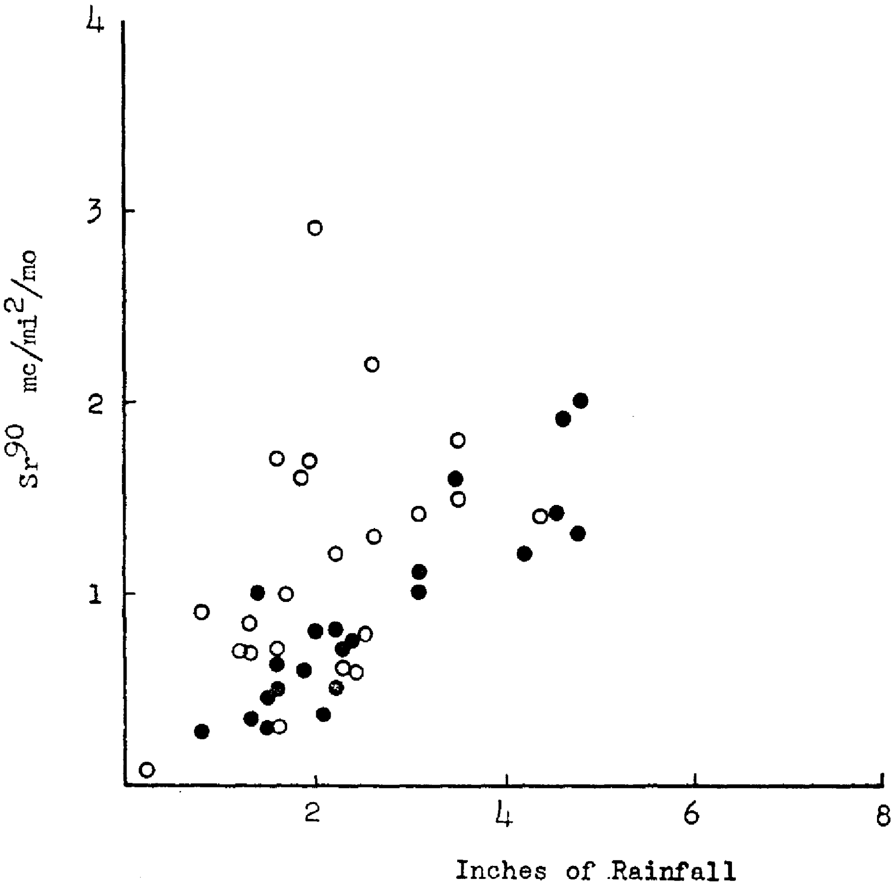

Figure 2b. Regression of Sr^{90} in rain water on the amount of rainfall in April, 1956.

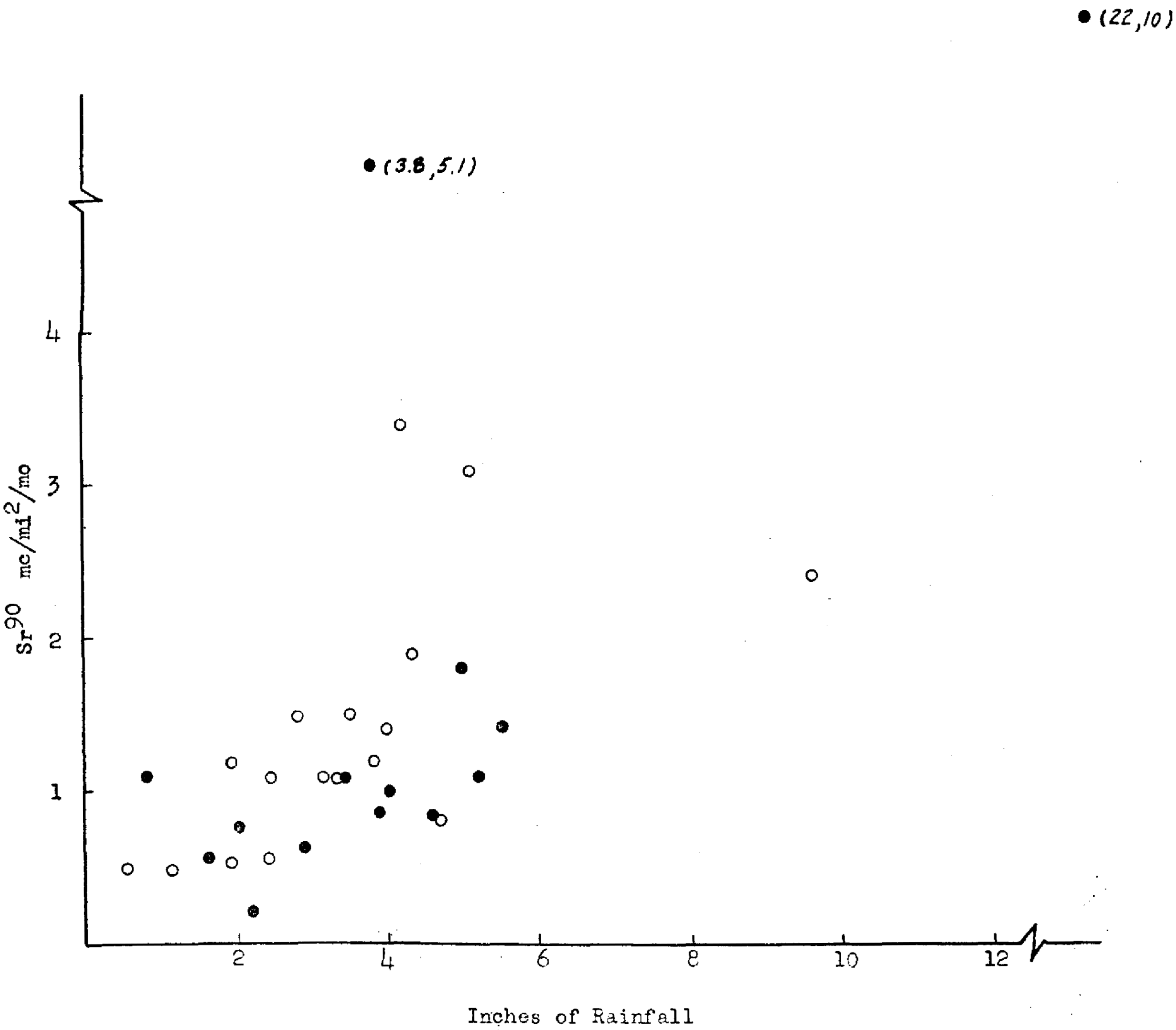

Figure 2c. Regression of Sr^{90} in rain water on the amount of rainfall in May, 1956.

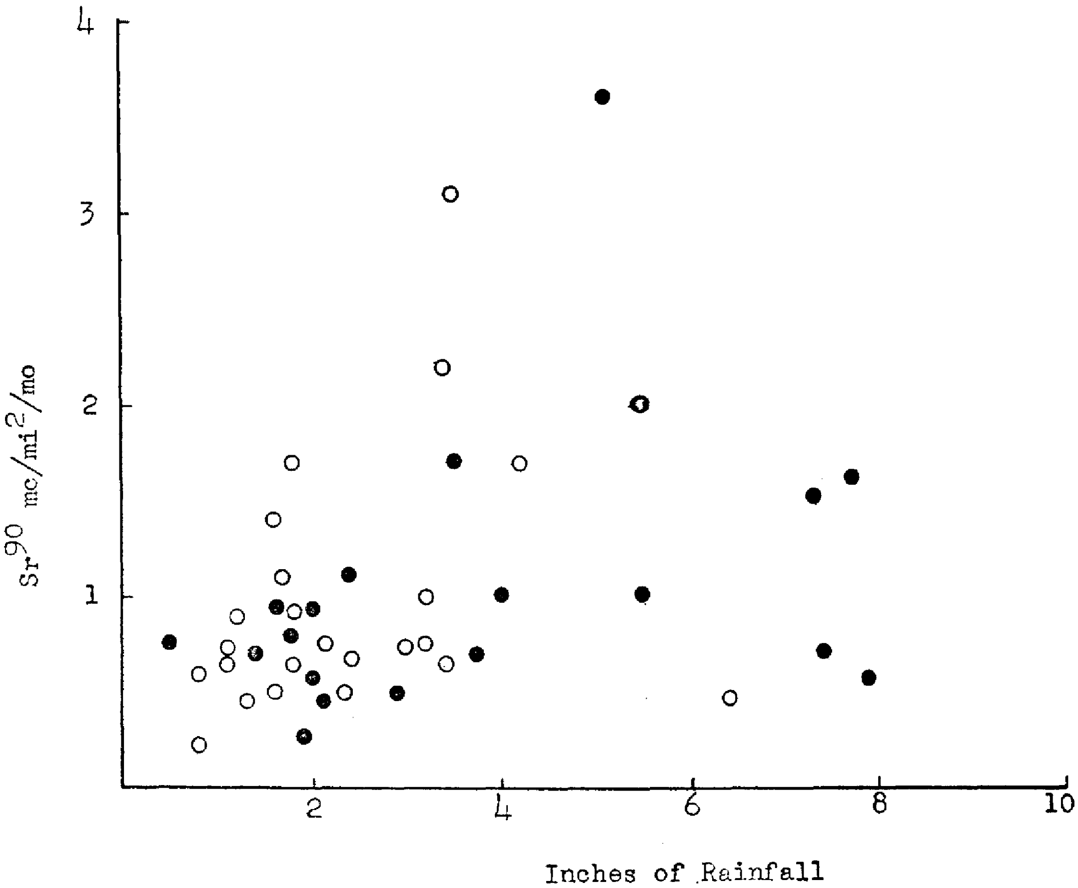

Figure 2d. Regression of Sr^{90} in rain water on the amount of rainfall from June, 1956.

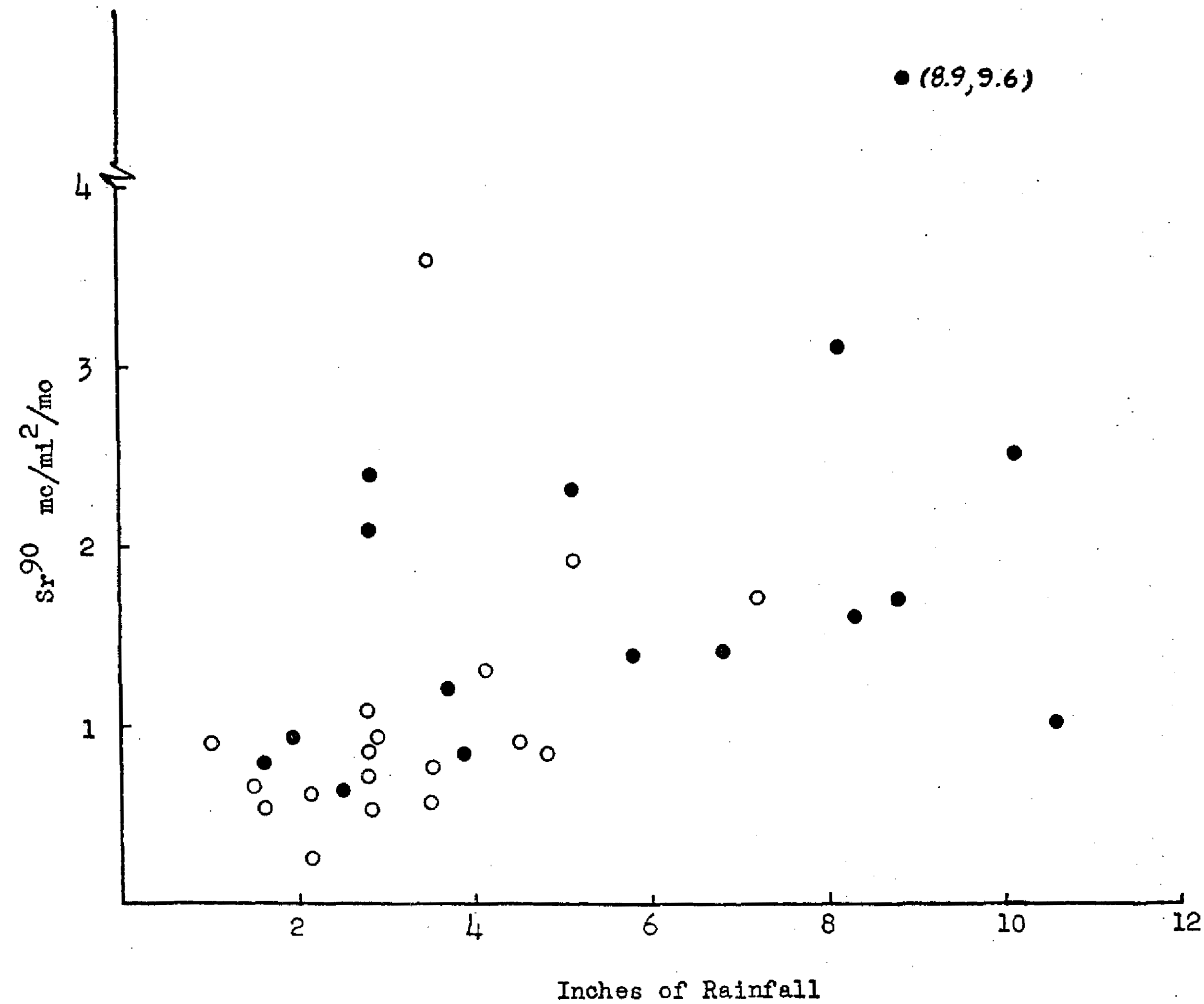

Figure 2e. Regression of Sr^{90} in rain water on the amount of rainfall in July, 1956.

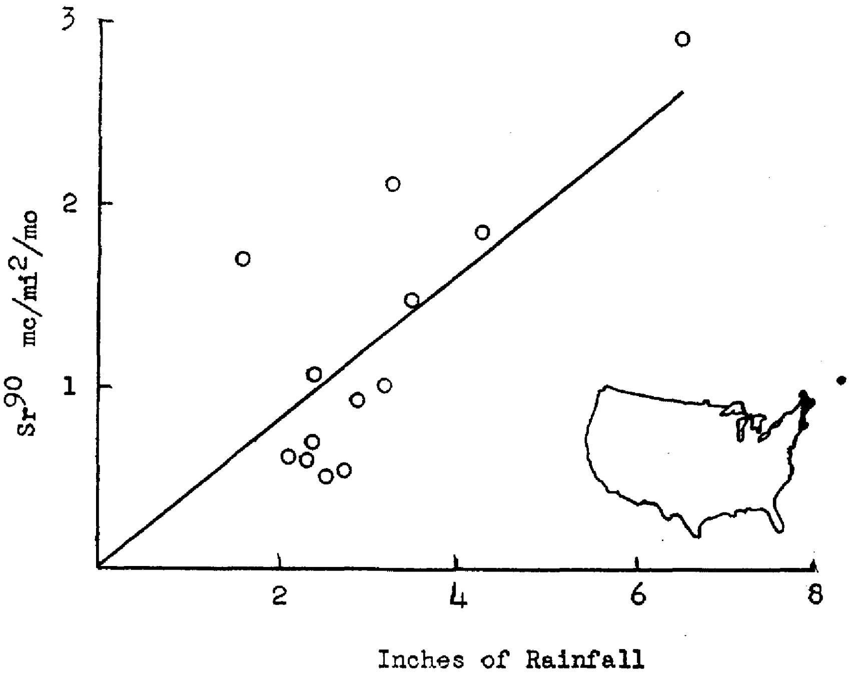

Figure 3a. Regression of Sr^{90} in rain water on the amount of rainfall collected March through July, 1956 at Caribou, Nantucket, and Stephenville.

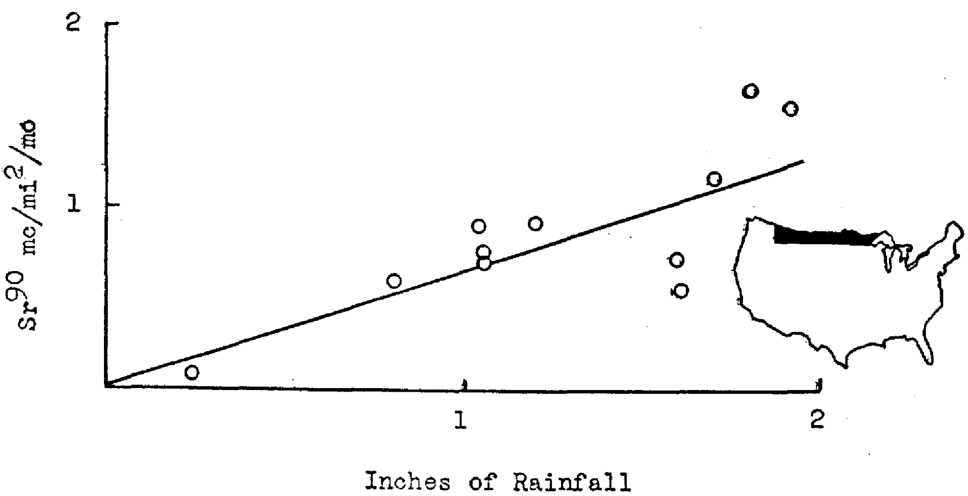

Figure 3b. Regression of Sr^{90} in rain water on the amount of rainfall collected March through July, 1956 at International Falls, Glascow, Helena, Boise, and Spokane.

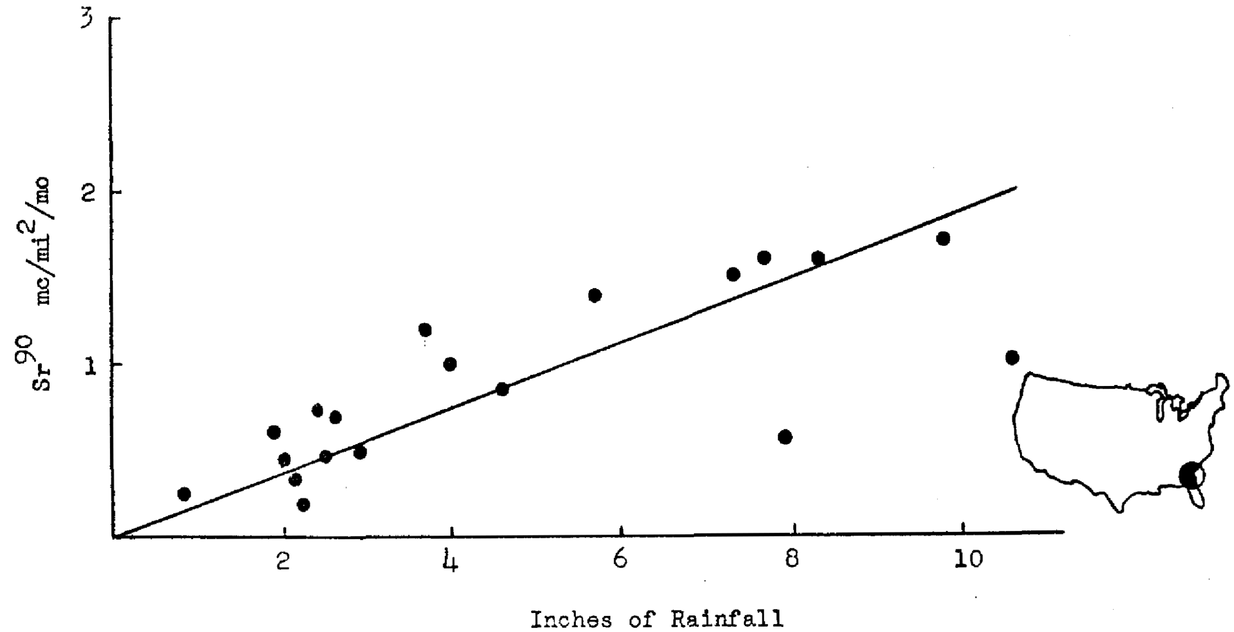

Figure 3c. Regression of Sr^{90} in rain water on the amount of rainfall collected March through July, 1956 at Tampa, Tallahassee, Jacksonville, and Charleston.

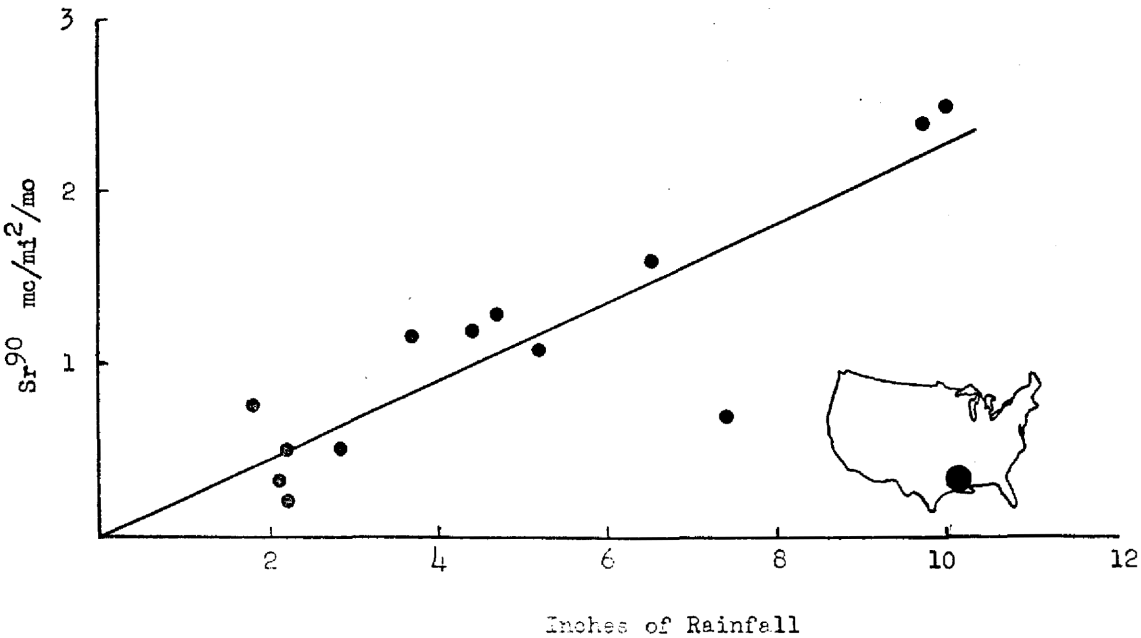

Figure 3d. Regression of Sr^{90} in rain water on the amount of rainfall collected March through July, 1956 at Mobile, Lake Charles, Jackson, and Little Rock.

From these plots it is obvious that activity is proportional to the amount of rainfall within each area. Correlation coefficients for all graphs are summarized in Table 4.

Table 4. Correlation coefficients for the Regression of Sr^{90} on inches of rainfall.

Fraction of total Sampling Area	Time of Sampling					
	March	April	May	June	July	March thru July
Total Sampling Area	0.77	0.57	0.86	0.31	0.47	0.60
Above 40° Latitude	0.46	0.45	0.63	0.37	0.42	0.43
Below 40° Latitude	0.95	0.87	0.90	0.66	0.37	0.72
Northeast						0.77
Northwest						0.78
Southeast						0.77
Southwest						0.87

The next step in the analysis of the rain water data is made by comparing Sr^{90} in rain to that measured by various pot type collectors. However, most of these devices collect total fallout and have sampling networks that do not coincide with the rain water stations. Therefore, a comparison of these results can only indicate the relative levels of rainout to total fallout. This comparison is shown in Table 5 in which the average values of fallout in rain water are obtained by considering 10 rainfall sampling stations nearest New Haven, Pittsburgh, and New York.

Table 5. Comparison of fallout (mc/mi^2/mo) in rain water to total fallout.[6]

Sampling Month	Air Force Rain Water: Average Total β Activity	Air Force Rain Water: Average Sr^{90}	New York Roof Pots: Total β Activity	New York Roof Pots: Sr^{90}	New Haven Dust Fall: Total β Activity	New Haven Dust Fall: Sr^{90}	Pittsburgh Rainfall: Sr^{90}
March	20	1.3	46	1.9	--	---	1.3
April	45	1.3	83	0.8	63	2.3	1.0
May	21	1.2	71	1.0	42	0.6	1.5
June	17	0.8	27	0.8	28	0.6	1.4
July	27	1.5	77	0.6	--	---	0.6

The best comparison between rain water data and total fallout should be obtained using gummed film data, since the gummed film network covers the same area as the rain water stations and operated over the same sampling period. The positioning of the two sampling networks is shown in figure 4. Because only 14 of the stations are duplicated, geographic extrapolation is employed to obtain values for the rain water sites that are not covered by gummed film stations. Distances of 100, 150, 200 and 300 miles were used as extrapolation radii, but it was found that the distance used made little difference in the final correlation. 150 miles was chosen as the optimum distance because, when circles of this radius were drawn around the rain water sites, a maximum number of gummed film stations fell within the given areas with a minimum number of circles overlapping.

With this scheme there are 11 results that may be compared in March; 30, in April; 20, in May; 25, in June, and 23 in July. The highest

Figure 4. Location of rain water and gummed film sampling sites in the United States.

correlation coefficient obtained, using the gummed film data[7] as predicted Sr^{90} and rain water data as measured Sr^{90}, is 0.49. This relationship is shown in figure 5, using the month of May as an illustration. The ratios of average Sr^{90} in rain to average Sr^{90} in gummed film, range from 1.9 to 45. Table 6 is a summary of this comparison.

Table 6. Comparison of Sr^{90} in gummed film to Sr^{90} in rain water.

Sampling Month	Average Sr^{90} in rain water ($mc/mi^2/mo$)	Average Sr^{90} in gummed film ($mc/mi^2/mo$)	Ratio	Correlation Coefficient
March	1.2	0.44	2.7	0.24
April	1.1	0.57	1.9	0.20
May	1.6	0.14	11	0.49
June	1.0	0.022	45	0.02
July	1.5	0.063	24	0.01

CONCLUSIONS

The relationship between fallout in rainfall with total fallout measurements using the pot type of collector is good, but there is poor agreement between the rain water data and gummed film measurements. It is believed that the Sr^{90} values calculated from gummed film activity are low due to incorrect arbitrary burst assignments used in the calculations.[6]

Considering only the rainfall data, no overall correlation exists between rainfall and the level of Sr^{90} activity. It is interesting that although the testing of atomic weapons takes place in southern latitudes, the Sr^{90} deposition is higher at northern latitudes. If the fallout was

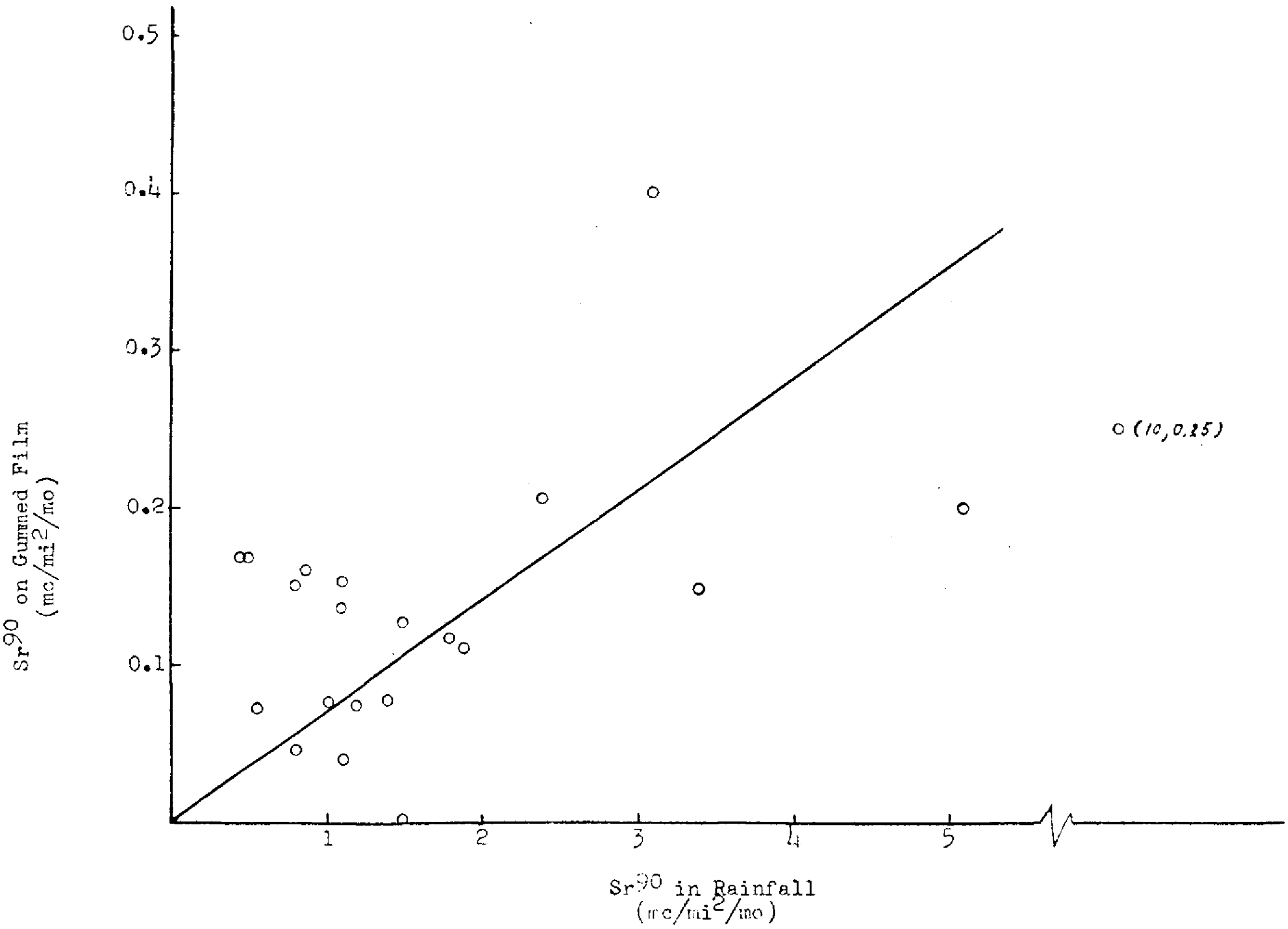

Figure 5. Regression of Sr^{90} in gummed film on Sr^{90} in rain water from 20 stations in May, 1956.

of recent tropospheric origin, this northward movement could be due to surface winds. However, the high percentage of Sr^{90} indicates that the debris is old and entered the troposphere from the stratosphere.

Since there is more Sr^{90} in the northern region, the activity levels in the troposphere are not uniform over the United States. However, when areas are chosen which are small enough to have nearly the same tropospheric activity levels, the Sr^{90} in rain water is proportional to the amount of precipitation.

There is some justification for accepting the theory that a selective entrance zone for stratospheric fallout exists. This is demonstrated in the initial separation of data, where northern sites show little correlation although they have a higher mean level per inch of rain. Rainout for the southern stations is definitely proportional to the amount of rainfall, suggesting a more uniform activity level in the atmosphere. It should be noted that no correlation for southern stations existed in July, when there was fresh fallout.

SUGGESTIONS

The validity of the assumptions made from this data suffer from several sources of error. In the event a more comprehensive study is undertaken in the future, there are several changes that should be made.

(1) The scope of the experiment should be extended to operate over a larger area and a longer period of time.

(2) Sampling methods should be improved to preclude missing parts of the rain sample.

(3) Provision should be made to assay total fallout at the sites of rainfall measurements.

References and Notes

(1) Instructions for Operation of Air Force Rain Gauges (AF - 1210).

(2) In a considerable number of sample aliquots, miscellaneous debris and insoluble oils were present. In these cases the samples were filtered and the residue discarded prior to analysis.

(3) Official Weather Bureau data was used to correct the Air Force total sample volume data at the suggestion of Dr. Christian Junge, of AFCRC and Mr. F. I. Sullivan of Skinner and Sherman. This was to compensate for portions of the sample missed when the collector was not opened in time to collect all the rain.

(4) In addition to the normal rain water sampling, another series of collections was run at West Newton, Massachusetts with the collector open at all times. No consistent relationship between the two sets of data was found at HASL, however, and both results were used in this report as the best approximation of activity levels at that station.

(5) Hallden and Harley, HASL Laboratory Report 56-9.

(6) J. Harley, et al, NYO Report No. 4862.

(7) HASL Fallout Summary, March through July, 1956.

(8) Appreciation is expressed to the HASL staff members who were associated directly and indirectly with this project. Among them were Helen W. Keller and Seymour Tarras, who helped in various phases of the analytical procedures.