The Occurrence of an Unusually High-Level Radioactive Rainout in the Area of Troy, N. Y.

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ON April 25, 1953, at 8:30 A.M. EDT, the seventh nuclear bomb in the spring series was detonated from a 300-ft tower at the Nevada proving ground. Thirty-six hours later, on the evening of April 26, an unusually violent electrical storm ended what had been a warm and sultry spring day in Troy—2300 mi from the proving ground. The storm, characterized by extremely high winds, hail, and torrential rains, was one of the worst flash storms to hit the area in recent years. It flooded streets and cellars, undermined buildings, and caused heavy damage.

The storm was unusual in another respect in that it, unknown to the residents of the area, had left in its wake an exceptionally high, though not hazardous, deposition of radioactive material. This became evident on the day following the storm when the background rates were determined for the G-M counters in the radiochemistry laboratory at Rensselaer Polytechnic Institute. The background rate for the shielded G-M counter located nearest the outside wall of the counting room was observed to be more than 3 times greater than the normal rate of about 30 counts/min. For each of the other G-M counters, the increase in background was less, the greater the distance of the counter from the outside wall. Outside the building, it was observed that the level of beta and gamma radiation on the pavement, sidewalks, soil, and so on, was great enough to be readily measured with portable radiation survey meters. It thus became evident that the extent of the rainout was much greater than that detected in the area from any previous nuclear detonation. Previously, the presence of fission products had been detected in rain and snow, but only after concentration and examination of the residue with sensitive counting equipment.

In order to evaluate the possibility of immediate radiological hazard resulting from the rainout and, at the same time, secure information on the characteristics of the deposited radioactive material, various types of radioactivity measurements were made for a variety of materials subjected to the rainout (*1*). The latter included asphalt and concrete pavement, pieces of paper and cloth, surface water left in puddles, leaves from burdock and dandelion plants, reservoir water, tap water, and asphalt roofing shingles.

Ground contamination was measured with a portable G-M type survey meter equipped with a G-M tube of wall thickness 30 mg/cm² and with a "Zeus" ionization chamber survey meter (*2*). Both instruments were calibrated for gamma radiation with a radium standard. Gamma-ray and beta-plus-gamma-ray measurements were made at distances of 1 in. and 3 ft above the ground. A few of the observed values are listed in Table 1. Although all values are expressed as meter readings in units of milliroentgens per hour (mr/hr), the values are significant for dosage calculations only for the gamma-ray measurements. As would be expected, the observed gamma-ray dosage rates were essentially independent of the height of the detector above the ground.

TABLE 1. Ground contamination.

Location	Days after arrival	Height of meter above ground (in.)	Meter readings (mr/hr)*	
			$\beta^- + \gamma$	γ
Downtown Troy	1.1	1	5	
Watervliet	1.1	1	6	0.4
R.P.I. campus†				
a)	0.7	1	4.5	
		36	0.75	0.3
b)	1.1	36	.8	.4
c)	3.5	1	1.2	.3
		36	0.5	.12
	5.5	1	.6	.10
		36	.2	.10
	7.5	1	.5	.10
		36	.2	.10
	9.5	1	.4	.08
		36	.12	.06
d)	3.6	1	15	1.3
	7.5	1	5.5	0.7
	9.5	1	4.5	.5
	2.1	1	120	6
	3.6	1	70	5
	7.5	1	15	1
	9.5	1	11	< 1

* The last four readings were made with a "Zeus" meter; all others were made with a G-M type meter.

† Four different locations on the campus are listed; location (d) is a "hot spot" on pavement near a drain spout.

In order to calculate the accumulated gamma-ray dosage that could have resulted from continuous exposure to the ground contamination, a value of 0.4 mr/hr was taken to be representative of the gamma-

ray dosage rate 1.1 days after arrival, and it was assumed that the rate of decay of the ground contamination was given by the $t^{-1.2}$ law. The accumulated gamma-ray dosage rate was found to be 55 mr for a 10-wk exposure. This is in addition to the accumulated dosage from natural background of about 25 mr, based on an observed average background rate of about 0.015 mr/hr for this area. For comparison, the accepted safe level is 3000 mr for a 10-wk period. It should be pointed out that it is customary to calculate the radiological hazard of ground contamination in terms of gamma-ray intensities only. Thus, it is assumed that people will not be in close contact with the ground for long periods of time and that shoes and clothing will absorb any beta radiation with a significant range in air.

The observed ground contamination in this instance was sufficient to serve as the basis for an exercise for the local civil defense radiological group. Although there were several days of rain immediately after the rainout, the activity was firmly adsorbed on the pavement and disappeared at a rate about equal to that for decay alone.

Autoradiographs showing the presence of fission products were obtained by placing Eastman No-Screen Medical X-ray film in contact with samples of leaves and other materials for exposure times of 24 hr. Porous materials, such as paper and cloth, and materials with a rough surface, such as wood, asphalt shingles, and burdock leaves, were found to have the greatest radioactivity. The distribution of fission products on the surfaces of a piece of asphalt shingle and a burdock leaf is illustrated in Fig. 1. In general, for each specimen, the autoradiograph consisted of many small circular spots, which were rather uniform in area, plus several large patches of irregular shape. The activity was very firmly held to these surfaces and could be only partially removed by treatment with hot concentrated hydrochloric acid.

An estimate of the surface activity in disintegrations per minute per square foot was obtained by beta counting samples cut from leaves, paper, and so forth. The samples, having an area of 3.14 cm², were cut with a cork borer and were mounted on flat circular copper disks 1 in. in diameter. Beta-activity measurements were made with calibrated G-M tubes having a window thickness of 2 to 3 mg/cm². The results are shown in Table 2, where the values listed for the arrival time were calculated by applying the $t^{-1.2}$ law to the April 25 detonation. The observed wide range of 0.2×10^6 to 13.5×10^6 disintegrations/min ft² is not surprising in view of the nonuniform surface distribution of fission products revealed by the autoradiographs. The contamination per square foot is comparable with that reported by Eisenbud and Harley (*3*) for fallout from the 1952 tests as settled dust at stations in Utah and Nevada in the 200 to 500 mi annulus around the test site.

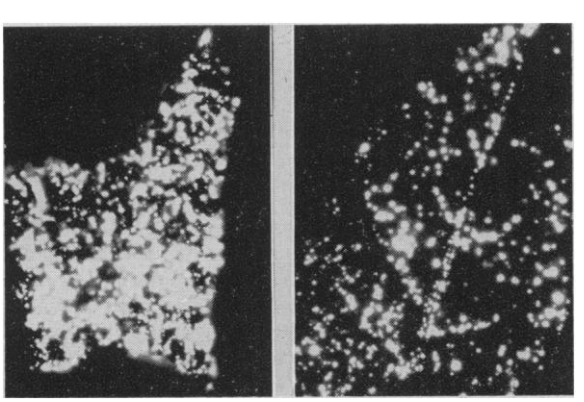

FIG. 1. Autoradiographs. On the left is a piece of asphalt shingle, 4 cm at the base. On the right is a burdock leaf, 6 cm maximum width, 9 cm length.

TABLE 2. Distribution of deposited radioactivity.

Sample	10^6 dis./min ft² at arrival time	Sample	10^6 dis./min ft² at arrival time
Burdock leaf*		Paper	13.5
1	3.9	Cardboard	8.8
2	3.4	Asphalt shingle	1.8
3	2.2	Dandelion leaf*	
4	2.1	1	1.5
5	1.8	2	0.6
6	1.1	3	0.5
7	0.6	4	0.3
8	0.3		
9	0.2		

* Samples were cut from several leaves.

A sample of rain water collected from a puddle on the asphalt pavement of the campus was dried down and counted with an end-window G-M tube. The activity was found to be 270 micromicrocuries per milliliter (μμc/ml) at the time of sampling, 0.7 days after arrival.

Four samples of water were taken from the Tomhannock Reservoir on April 28, 1.8 days after arrival. This reservoir is one of several unfiltered supplies that serve Troy. It is located about 6 mi northeast of the city and has a capacity of 13.7 billion gallons. In addition, four samples of tap water were collected during the period April 27 to May 12. All reservoir and tap water samples (2 liters) were concentrated by evaporation in 3-liter porcelain evaporation dishes, which were heated on electric hot plates in a chemical hood. The residues were transferred to tared nickel-plated steel cupped planchets 1 in. in diameter and ¼ in. deep. A polyethylene policeman was used during each quantitative transfer operation. The samples were dried under a heat lamp, reweighed, and beta counted with the end-window G-M tubes. In the calculation of the activity in micromicrocuries per milliliter, a self-absorption correction was applied. This correction was

TABLE 3. Radioactivity of Tomhannock reservoir water and Troy tap water.

Sample	Days after arrival*	Activity at collection time (μμc/ml)
Reservoir water		
1) Surface water near intake	1.8	0.80
2) Surface water near intake	1.8	.74
3) Raw water before chlorination	1.8	.96
4) Raw water before chlorination	1.8	.58
Tap water†		
1)	1.1	2.63
2)	2.0	1.21
3)	6.1	0.24
4)	16.1	.034

* Time when collected.
† Not from the Tomhannock supply. All samples were from the same tap.

estimated from external absorber measurements. Table 3 is a compilation of the data for reservoir and tap water samples.

During the first day after arrival, the activity of drinking water was greater than 1 μμc/ml or about 100 to 1000 times greater than the natural radioactivity generally associated with surface and ground water, namely 10^{-11} to 10^{-12} gram of radium per liter (*4*) or about 10^{-2} to 10^{-3} μμc/ml. About 50 curies of fission products were contained in the Tomhannock Reservoir alone during the first day after the rainout. It is of interest to note that the highest activity of the water monitored near the Nevada test site, extrapolated to 3 days after detonation, during the spring 1953 test series was 87 μμc/ml (*5*). The highest activity of surface water examined near the Nevada test site, at 3 days after detonation, during the spring 1952 test series was only 1.1×10^{-2} μμc/ml (*6*). During the same period of 1952, the maximum activity observed for the surface waters of Massachusetts was 0.14 μμc/ml (*7*). For comparison, some of the published values for the maximum permissible concentrations of fission products in drinking water are compiled in Table 4.

TABLE 4. Limits for fission-product concentration in drinking water.

Concentration	Reference
90,000 μμc/ml: acceptable beta-gamma activity for water to be used on an emergency basis for a 10-day consumption period immediately following a nuclear explosion.	*8*
30,000 μμc/ml: acceptable beta-gamma activity for water to be used on an emergency basis for a 30-day consumption period immediately following a nuclear explosion.	*8*
5,000 μμc/ml: total fission-product activity, 3 days after formation, such that the water could be used for any period of time.	*6*
70 μμc/ml: maximum permissible concentration of Sr^{89} for continuous exposure.	*9*
0.8 μμc/ml: maximum permissible concentration of Sr^{90} (with Y^{90}) for continuous exposure.	*9*
0.1 μμc/ml: provisional permissible concentration of an unknown mixture of beta or gamma emitters.*	*9*

* This maximum concentration is intended for use as a provisional guide when only the gross activity is known. If essentially all of the activity can be accounted for, the maximum permissible concentrations are those that have been established for the radioisotopes in the mixture. In general, the values (9) are much higher than 0.1 μμc/ml for radioisotopes present in significant quantities in fallout or rainout.

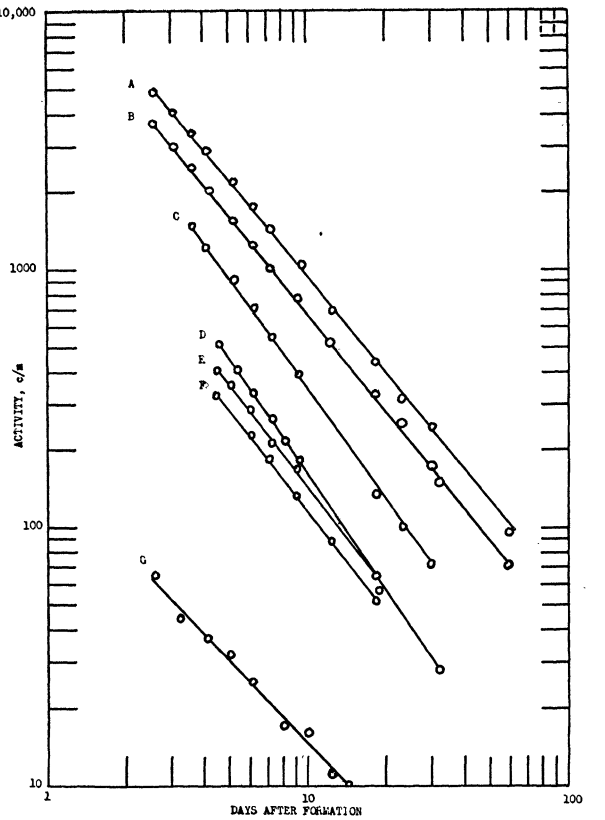

FIG. 2. Decay curves for: *A*, asphalt shingle; *B*, cloth; *C*, tap water sample No. 1; *D*, tap water sample No. 2; *E*, reservoir water sample No. 3; *F*, reservoir water sample No. 1; *G*, "excess" background rate for G-M counter.

The rate of decay of the fission-product activity was determined for the reservoir and tap water and samples of other materials. A few decay curves, including

TABLE 5. Exponent in the decay equation, $A = A_1 t^{-n}$.

Sample	n	Sample	n
Cloth	1.26	Asphalt shingle	1.26
Reservoir water		Tap water	
1)	1.30	1)	1.44
2)	1.27	2)	1.46
3)	1.30	3)	1.52
4)	1.37		

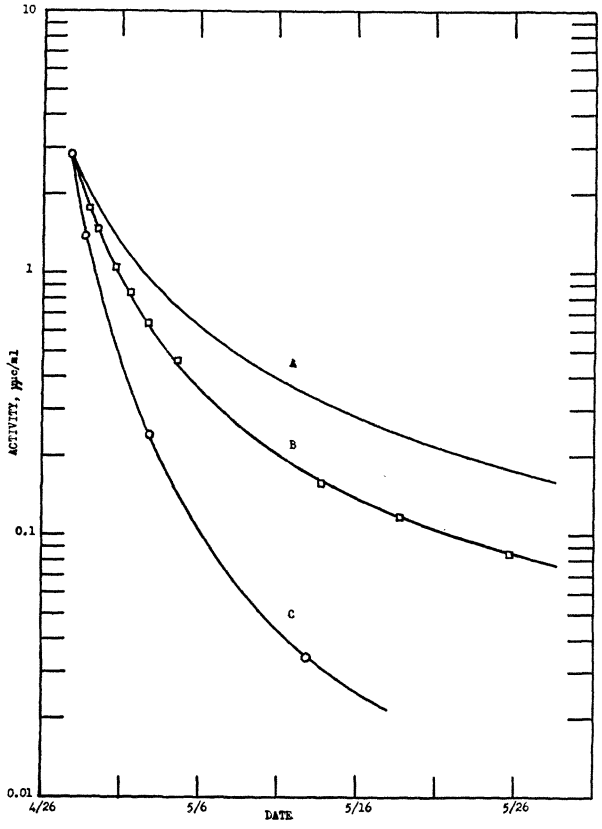

FIG. 3. Dieout curve for tap water: *A*, hypothetical decay for tap water sample No. 1 according to the $t^{-1.2}$ law; *B*, observed decay for tap water sample No. 1; *C*, observed dieout for tap water.

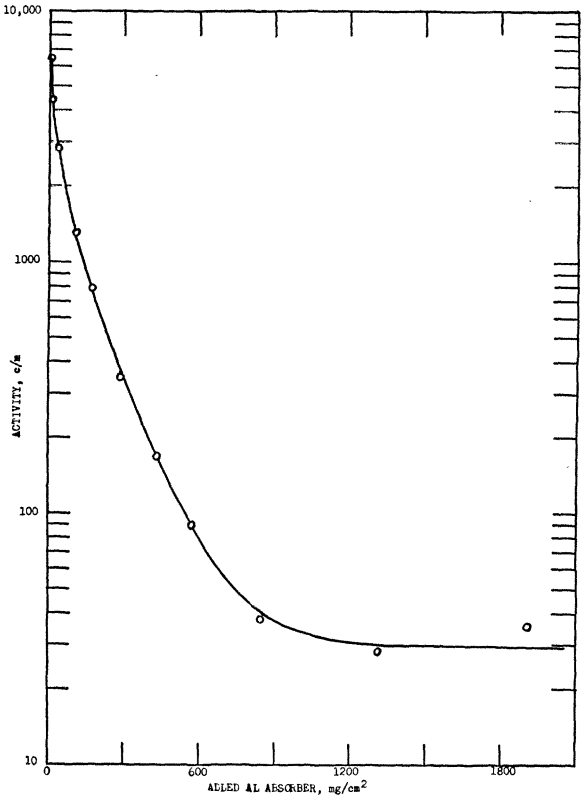

FIG. 4. Beta-ray absorption curve.

the curve for the "excess" background rate for one G-M counter, are illustrated in Fig. 2. When the decay curves are represented by an equation of the type $A = A_1 t^{-n}$, the values of n obtained vary from 1.26 to 1.52, as is shown in Table 5. Although the differences are not very great, it appears that the activity of the tap water samples decayed more rapidly than that found on the surfaces of various materials. Apparently, some fractionation of the fission-product mixture had occurred in the case of the tap water.

The dieout—that is, over-all rate of disappearance of fission products from tap water—is shown in Fig. 3. For comparison, the rate of decay of the first tap water sample collected is shown together with the rate expected on the basis of the $t^{-1.2}$ law. The dieout for tap water is seen to be greater than the radioactive decay rate during the period of 15 days after the arrival of the fission products. During this same period, the turbidity of the water, which was very marked immediately after the storm, slowly decreased.

Beta-ray absorption measurements were made for several samples. A typical absorption curve obtained for a piece of contaminated cloth 0.8 day after arrival is shown in Fig. 4. Although the curve is typical for a complex mixture of beta emitters, it may be resolved into at least three groups, for which the average energies are approximately 0.8, 0.3, and 0.1 Mev.

References and Notes

1. I wish to acknowledge the cooperation and assistance of several students, particularly A. J. Hogan and C. W. Williamson, who generously assisted in the preparation and counting of several of the samples during the hours immediately following the rainout.
2. Except for very weak beta radiation, the G-M type survey meter is the more sensitive, having an upper limit of 20 mr/hr. Although the ionization type meter will detect alpha and weak beta radiation, it is not so satisfactory for gamma-ray measurements below 10 mr/hr, since it is designed for higher level gamma-ray measurements.
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