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Los Alamos County, New Mexico

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MASTER

STORM RUNOFF AND TRANSPORT OF RADIONUCLIDES IN DP CANYON, LOS ALAMOS COUNTY, NEW MEXICO

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ABSTRACT

Effluents from the waste treatment plant at Los Alamos Scientific Laboratory's Technical Area 21 are released into DP Canyon. The radionuclides remaining in the effluents are bound to stream-channel sediments which are later carried out of the canyon by storm runoff.

A study was made to determine the runoff volume, the suspended-sediment load, and the amount of radioactivity carried out of DP Canyon by storm runoff. During the summer of 1967, precipitation resulted in 23 runoff events that carried $\approx 88\,000$ kg of suspended sediments out of the canyon in $\approx 36\,800$ m³ of water. Less than 74 μ Ci of gross alpha emitter and $\approx 40\,100$ μ Ci of gross beta were carried out of the canyon in solution. The suspended sediments carried out ≈ 70 μ Ci of gross alpha emitters and $\approx 11\,300$ μ Ci of gross beta emitters. About 31 000 μ Ci of ^{90}Sr left the canyon in solution, as did traces of ^{238}Pu , ^{239}Pu , and ^{241}Am .

I. INTRODUCTION

Certain liquid wastes produced by the Los Alamos Scientific Laboratory contain small amounts of radioactivity. These wastes are treated chemically and by ion exchange to reduce the radioactivity before the effluents are released into canyons adjacent to the treatment plants. As the effluents move down the canyons in the intermittent flow in the stream channels, any remaining radioactivity is bound to the bed sediments, thereby reducing the amounts of radioactivity in surface flow and shallow ground water in the alluvium.

In DP Canyon, which will be discussed here, the radioactivity concentrations in the bed sediments decrease downgradient from the point of effluent outfall. Radioactivity

does not build up in the sediments at the outfall because the radionuclides and sediments are dispersed and carried down the canyon by storm runoff.¹

The purpose of the present study was to estimate the amount of radioactivity transported by storm runoff from DP Canyon, which receives low-level radioactive effluents from Technical Area 21 (TA-21). The report is based on data collected in the canyon during the summer of 1967.

TA-21 is located on a small mesa that is part of the Pajarito Plateau. Effluents are released into DP Canyon north of the technical area (Fig. 1). The stream in the canyon is intermittent and arises from low-level radioactive industrial effluents,

Fig. 1. Drainage area of DP Canyon, showing effluent outfalls and gaging station.

sewage effluents, and occasional storm runoff.

DP Canyon enters Los Alamos Canyon near the center of the Plateau. Stream flow in Los Alamos Canyon also is intermittent and is dependent on storm runoff. The canyon is tributary to the Rio Grande which is 11.2 km to the east.

The amount of suspended sediments and volume of storm runoff in DP Canyon were determined at a gaging station at the mouth of the canyon. Radiochemical analyses were made of the suspended sediments and the solution in the runoff.

The TA-21 waste treatment plant releases $\approx 950 \text{ m}^3$ of effluent per month into DP Canyon in $\approx 75\text{-m}^3$ "slugs." The main radionuclides in the effluent during the summer of 1967 were plutonium, americium, and strontium. Mixed fission products were present in minor amounts. The sewage treatment plant releases $\approx 1900 \text{ m}^3$ of effluent per month into the lower part of the canyon (Fig. 1). The release of sewage effluents is continuous, but the discharge is slightly greater during the working day. The industrial and sewage effluents flow eastward

down the canyon, moving into the thin alluvium in the mid-reaches of the canyon. The major area of surface water loss is in the lower part of the canyon where the alluvium thickens and is underlain by a nonwelded tuff.

II. CHANNEL CHARACTERISTICS

DP Canyon heads on the Pajarito Plateau and is 2.4-km long (above its junction with Los Alamos Canyon). Its drainage area is $\approx 1.6 \text{ km}^2$, of which $\approx 0.5 \text{ km}^2$ lies in a developed area (roads, buildings, parking areas, and part of an airstrip). The upper 1.6 km of the canyon is cut into nonwelded and moderately welded units of the Tshirege Member of the Bandelier Tuff.² The channel gradient here is $\approx 19 \text{ m/km}$. Grasses and small shrubs grow along the banks. The channel contains a thin section of sands and gravels, with occasional exposure of tuff.

The lower 0.8 km of the canyon is deep and narrow, cut through a welded unit of tuff underlain by a nonwelded unit of tuff. The channel fills the narrow canyon floor and is strewn with large boulders and blocks of tuff dislodged from the canyon walls.

The gradient in this section is ≈ 144 m/km, and there are numerous waterfalls, the largest having a drop of 6 m. The channel is composed of sands and boulders, and the alluvium thickens to ≈ 5.5 m at the junction with Los Alamos Canyon.

The cobbles and boulders in the canyon's stream channel are mainly of latite and rhyolite that were inclusions in the ash-flows. Numerous, also, are cobbles and boulders of the more welded types of tuff. The cobbles and boulders are in a matrix of sand and gravel. Silt-clay and very fine sand-size fractions make up $>50\%$ by weight of the tuff weathered in place and $>50\%$ of the suspended sediments, whereas the sediments in the stream channel contain $\approx 2\%$ of that size fraction (Table I). The finer material is sifted out of the channel sediments and is transported out of the canyon by storm runoff.

The silt and clay are largely montmorillonite and illite which are weathering products of the tuff.³ Montmorillonite and illite have medium ion-exchange capacities in river sediments in the United States.⁴ These clay minerals are believed to be responsible for the effectiveness of the Los Alamos soil in removing plutonium from waste solutions.³

Sediments in the sand-size class, 0.062- to 2-mm-diam, are largely quartz and sanidine crystals and crystal fragments. Also present are small amounts of rock fragments of tuff, pumice, rhyolite, latite, and some mafic minerals. Sediments in the very fine gravel-size class, 2- to 4-mm-diam, are largely tuff, pumice, latite, and rhyolite rock fragments. The large particle-size material in the stream channel also takes up some of the radionuclides, perhaps because of the presence of clay coating on the crystals or rock fragments.

III. STORM RUNOFF

A gaging station (Fig. 1) with a continuous water-stage recorder was constructed at the mouth of DP Canyon in May 1967 to

permit measurement of storm runoff from the canyon. The control was a 91-cm rectangular weir. A stage-discharge rating curve was determined by current-meter and dye-dilution measurements.

Precipitation over the area resulted in 23 runoff events in DP Canyon from May through September 1967. The duration of flow, mean discharge, and volume of flow are given in Table II. The mean discharge ranged from 6-118 L/s, while runoff ranged from 80-9000 m³. Total runoff for the period was $\approx 36\,800$ m³.

IV. SEDIMENT TRANSPORT

Soils in the DP Canyon drainage area are derived from weathering of tuff. Overland runoff moves loose, erodible particles from the land surface into the stream channel. Once in the channel, these sediment particles are transported by stream flow either in suspension or in solution.

Only the suspended sediments are considered here in the transport of radionuclides. These sediments are classified as having a mean diameter <6 mm (6 mm is the intake size of the DH-48 sampler, and the single-stage and cumulative samplers used in the study).

Single-stage samplers were installed at the gaging station 8 and 38 cm above the crest of the weir to collect suspended-sediment samples during the initial part of each runoff event.⁵ A DH-48 sampler was used to collect additional sediment samples from the flow during both the initial part and the tailoff of the event. Sediment concentrations were then determined. A sediment-concentration graph was constructed from these data and served as a basis for estimating suspended-sediment concentrations. For each flow event the sediment concentrations were integrated with volume of discharge. The mean suspended sediment concentration and total suspended-sediment load for each flow event are shown in Table II, along with the duration of flow, the mean discharge, and volume.

The largest suspended-sediment load to pass the gaging station in a single event was 29 000 kg in a total flow volume of 8410 m³ on August 10, when the weather station recorded 2 cm of precipitation in a 6-h period. A maximum discharge of 1190 l/s occurred in the second hour of the event and had an estimated mean suspended-sediment concentration of $\approx 28\,600$ mg/l.

The second largest suspended-sediment load was 22 000 kg in a total flow volume of 9000 m³ during July 16-18. Precipitation for a 17-h period on July 16 and 17 was 4.5 cm. The maximum discharge was 680 l/s during the third hour of the event and the mean sediment concentration was 21 400 mg/l.

One of the smaller runoff events occurred between 0200 and 1300 on August 11, when 400 m³ of flow transported ≈ 200 kg of suspended sediment. Precipitation for the period was 1.2 cm. The maximum discharge of ≈ 25 l/s was reached in the first hour and had a mean suspended-sediment concentration of 6000 mg/l. The stream channel and underlying tuff were saturated by previous runoff which had occurred almost daily since July 30. Runoff from the second hour until the conclusion of the event was from bank storage, sewage effluent, and release of industrial effluent.

The storm runoff of 36 800 m³ that occurred during the 5-month period of study carried $\approx 88\,000$ kg of suspended sediment past the gaging station.

V. RADIOACTIVITY IN STORM RUNOFF

Cumulative samplers (plastic bottles with 6-mm-diam intake) were used to collect samples of water-sediment mixtures during 9 of the 23 runoff events. The intakes, designed to reduce the velocity of flow into the sampler, were placed at the crest of the weir and at 30 and 61 cm above the crest. The water-sediment mixtures were prepared for analysis by allowing the suspended sediments to settle out, then decanting the clear portion and filtering to remove any sediment remaining in suspension. Chemical

and radiochemical analyses were made of the solution. The amount of suspended sediments was so limited that only gross alpha and beta determinations could be made. Results for sediments were above the natural background of 1.4 and 1.2 pCi/g for gross alpha and beta concentrations, respectively, found in adjacent canyons that do not receive industrial effluents.

A. Radioactivity in Solution

Chemical analyses were made for select ions (Table III). The ion concentrations were slightly higher than expected. The effluents may have evaporated during dry periods, with consequent concentration and precipitation of some of the ions into the channel sediments. Storm runoff would redissolve the precipitates, resulting in ion concentrations slightly higher than normal. The basic (pH >7.0) runoff would facilitate ion exchange and adsorption of most radionuclides by the silt- and clay-size fraction of the sediments.⁶

Gross alpha emitters in solution were <2 pCi/l; gross beta emitters ranged from 520-2180 pCi/l. Traces of ²³⁸Pu, ²³⁹Pu, and ²⁴¹Am were found in solution (Table IV). The presence of considerable amounts of ⁹⁰Sr may account for the high gross beta. Radium-226 and ²³⁷Cs were below the respective limits of detection of 0.15 and 240 pCi/l.

Table V shows the variational trends in gross beta and strontium concentrations during the summer. There was no variational trend for plutonium and americium concentrations from one runoff event to the next.

B. Radioactivity in Suspended Sediments

The uptake of radionuclides from solution by channel sediments is the rule rather than the exception.⁷ The silt- and clay-size fraction of sediment has the greatest capacity for ion exchange and adsorption of radionuclides. This capacity decreases with increasing particle size. In the stream channel, sand and gravel make up the bulk of the sediments and there are only small amounts of silt and clay. However, in the storm runoff the suspended sediments are composed

mainly of the silt- and clay-size fraction, and thus there is a greater capacity for adsorption and transport of radionuclide than with sand and gravel. There was no variational trend in gross alpha from one event to another, whereas the gross beta emitters exhibited a trend (Table VI) similar to that found when they were in solution (Table V).

VI. TRANSPORT OF RADIONUCLIDES

Radiochemical analyses were made of runoff samples (solution and suspended sediments) collected from 9 of the 23 runoff events. On the basis of the average concentrations of these samples, an estimate was made of the total amount of gross alpha and gross beta emitters carried from the canyon (Table VII).

The gross alpha emitters were transported in solution and with the suspended sediments. Less than 74 μCi was carried out in solution and an estimated 70 μCi were transported with suspended sediments.

The gross beta emitters also were present in solution and in the suspended sediments. An estimated 40 100 μCi were carried out of the canyon in solution and $\approx$ 11 300 μCi were carried out with suspended sediments.

An estimated 31 000 μCi of ^{90}Sr left the canyon in solution. The amounts of ^{238}Pu , ^{239}Pu , and ^{241}Am transported in solution were estimated at 5.9, 7.0, and 9.2 μCi , respectively.

REFERENCES

1. W. D. Purtymun, G. L. Johnson, and E. C. John, "Distribution of Radioactivity in the Alluvium of a Disposal Area at Los Alamos, New Mexico," U.S. Geol. Survey Prof. Paper 550-D (1966).
2. R. L. Griggs, "Geology and Groundwater Resources of the Los Alamos Area," U.S. Geol. Survey Water-Supply Paper 1753 (1964).
3. E. Staritzky, "Report on Petrographic Examination of Local Soils," Los Alamos Scientific Laboratory report LA-741 (1949).
4. V. C. Kennedy, "Mineralogy and Cation-Exchange Capacity of Sediments from Selected Streams," U.S. Geol. Survey Prof. Paper 433-D (1965).
5. U.S. Inter-Agency Committee on Water Resources, "Determination of Fluvial Sediment Discharge," U.S. Govt. Printing Off., Washington, DC (1963).
6. J. S. Hosking, "The Cation-Exchange Capacity of Soils and Soil Colloids," Council for Sci. and Ind. Res. J. U21 (1948).
7. W. W. Sayre, H. P. Guy, and A. R. Chamberlain, "Uptake and Transport of Radionuclides by Stream Sediments," U.S. Geol. Survey Prof. Paper 433-A (1964).

TABLE I

AVERAGE PARTICLE-SIZE DISTRIBUTION OF WEATHERED TUFF, CHANNEL
AND SUSPENDED SEDIMENTS^a

<u>Classification</u>	<u>Particle Diameter (mm)</u>	<u>Weathered Tuff (%)</u>	<u>Channel Sediment (%)</u>	<u>Suspended Sediment (%)</u>
Silt and clay	< 0.062	42	1.5	35
Very fine sand	0.062 - 0.125	9	0.5	17
Fine sand	0.125 - 0.250	10	5	15
Medium sand	0.250 - 0.500	12	12	13
Coarse sand	0.500 - 1.00	16	39	14
Very coarse sand	1.00 - 2.00	10	37	6
Very fine gravel	2.00 - 4.00	1	5	0

^aAverage of five analyses.

TABLE II
DISCHARGE CHARACTERISTICS FOR 23 RUNOFF EVENTS IN DP CANYON

<u>Date (1967)</u>	<u>Duration of Flow (s)</u>	<u>Mean Discharge (l/s)</u>	<u>Volume (m³)</u>	<u>Suspended Sediments</u>	
				<u>(Mean Concentration) (mg/l)</u>	<u>(kg)</u>
May 21	7 560	43	330	2 000	650
June 3	11 500	89	1 000	3 400	3 500
July 8	3 600	51	180	3 000	550
July 15	9 400	34	320	1 300	420
July 16-18	118 000	76	9 000	2 500	22 000
July 30	6 120	28	170	2 900	500
July 31	11 500	28	320	2 100	680
Aug. 1	10 800	8	90	1 700	100
Aug. 2-3	42 500	23	980	800	800
Aug. 5	21 600	6	100	1 000	100
Aug. 7	20 900	11	230	700	200
Aug. 8	15 800	17	270	800	200
Aug. 9	32 400	99	3 200	3 400	11 000
Aug. 10	71 300	118	8 410	3 400	29 000
Aug. 11	53 300	8	400	400	200
Aug. 19	25 900	68	1 800	2 500	4 400
Aug. 30-31	88 600	26	2 300	1 000	2 300
Sept. 4-5	10 100	8	80	1 600	100
Sept. 6-7	59 800	45	2 700	1 400	3 800
Sept. 7-8	28 800	17	490	1 000	490
Sept. 9	32 800	40	1 300	1 400	1 800
Sept. 9	24 100	14	340	600	200
Sept. 25-26	89 600	31	2 800	1 800	5 000
APPROX TOTAL -		-	36 800 ^a	-	88 000 ^a

^aRounded off to three significant figures

TABLE III
CHEMICAL ANALYSIS OF SOLUTION IN STORM RUNOFF

<u>Determination</u>	<u>Units</u>	<u>Range^a</u>		
		<u>Min (pCi/l)</u>	<u>Max (pCi/l)</u>	<u>Av (pCi/l)</u>
Chloride	mg/l	15	50	36
Fluoride	mg/l	2	7	4
Nitrate	mg/l	0.3	2.0	0.9
Dissolved solids	mg/l	221	518	304
Conductivity	μmho/cm	270	680	405
pH	-	7.8	9.2	8.4

^aNine analyses

TABLE IV
IN-SOLUTION RADIOACTIVITY IN STORM RUNOFF

<u>Determination</u>	<u>Range^a</u>		
	<u>Min</u> <u>(pCi/ℓ)</u>	<u>Max</u> <u>(pCi/ℓ)</u>	<u>Av</u> <u>(pCi/ℓ)</u>
Gross alpha	< 2		
Gross beta	520	2180	1090
Plutonium-238	<0.05	0.25	0.16
Plutonium-239	0.08	0.27	0.19
Americium-241	<0.05	1.07	0.25
Strontium-90	360	2160	850

^aNine analyses.

TABLE V
GROSS BETA AND STRONTIUM-90 IN RUNOFF
SOLUTION

<u>Date</u> <u>(1967)</u>	<u>Gross Beta</u> <u>(pCi/ℓ)</u>	<u>Strontium-90</u> <u>(pCi/ℓ)</u>
July 9	2180	2160
July 16	1230	905
Aug. 1	1180	920
Aug. 2	915	725
Aug. 7	625	360
Aug. 9	1080	745
Aug. 11	870	685
Aug. 19	520	365
Sept. 9	1070	800

TABLE VI
GROSS ALPHA AND BETA IN SUSPENDED
SEDIMENTS OF RUNOFF

<u>Date</u> <u>(1967)</u>	<u>Gross Alpha</u> <u>(pCi/g)</u>	<u>Gross Beta</u> <u>(pCi/g)</u>
July 8	0.7	249
July 15	0.9	172
July 18	1.0	119
July 31	0.3	111
Aug. 3	0.8	92
Aug. 7	1.2	133
Aug. 9	1.1	139
Aug. 11	0.4	95
Aug. 19	0.6	42
AVERAGE	0.8	128

TABLE VII
AMOUNT OF RADIONUCLIDES TRANSPORTED
IN STORM RUNOFF

<u>In Solution</u>	<u>Estimated Microcuries</u>
Gross alpha	< 74
Gross beta	40 100
Plutonium-238	5.9
Plutonium-239	7.0
Americium-241	9.2
Strontium-90	31 000
<u>In Suspended Sediments</u>	
Gross alpha	70
Gross beta	11 300