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DEPARTMENT OF BIOPHYSICS AND NUCLEAR MEDICINE
LABORATORY OF NUCLEAR MEDICINE AND RADIATION BIOLOGY

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NOTES ON THE DEPOSITION OF FALLOUT IN RELATION TO TOPOGRAPHY AND
LOCAL METEOROLOGICAL CONDITIONS

By

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ABSTRACT

This study was made as part of an effort to collect radioactive effluents released during the test operation of a Kiwi reactor (Kiwi B-1a) on December 7, 1961. Granular fallout collectors and cheese-cloth aerosol collectors were prelocated along roads approximating arcs of 5, 16, and 37 miles from the reactor test cell at the Nevada Test Site. Each of these arcs crossed successively lower and wider parts of a gently sloping valley. A last-minute shift in wind direction carried the effluent cloud away from the prelocated sampling devices. Apparently, the cloud was trapped until nightfall in an inversion layer from 2000' to 3500' feet above the surface.

During the night following the reactor test, tropospheric or stratospheric fallout probably derived from nuclear detonations in the U.S.S.R. (but no short-lived fission products) were deposited on the above-mentioned sampling devices. Due to the influence of shallow-valley inversion and cold air drainage, the pattern of this deposition was closely related to the local topography. The beta-gamma activity deposited on samplers at low elevation (presumably below the valley inversion layer) was less than that deposited on samplers at higher elevations. The highest levels of beta-gamma activity were detected on samplers which had been located directly in the most probable pathway of nocturnal cold-air drainage.

It has been suggested, on the basis of these findings, that further studies of fallout deposition in relation to local topographic and micro meteorological conditions might explain the local heterogeneity of soil, plant, and animal contamination by fallout and/or reactor effluents.

NOTES ON THE DEPOSITION OF FALLOUT IN RELATION TO TOPOGRAPHY AND LOCAL METEOROLOGICAL CONDITIONS

INTRODUCTION

This study was made while attempting to collect samples of radioactive effluent released during the test operation of a Kiwi reactor (Kiwi B-1a). Our objective was to compare particulate and aerosol reactor effluents as deposited on horizontal and vertical surfaces at various distances downwind from the reactor.

The test occurred on December 7, 1961, but the full-power run was cut to about 1/10th of its scheduled duration. Only a small amount of radioactive effluent was released; and a last-minute shift in wind direction carried the cloud away from our sampling devices which had been prelocated, in the expectation of northeasterly winds, along roads to the south and southwest of the test cell (see Figure 1.).

During the night of December 7-8, traces of short-lived fission products were detected in air samples collected by the U. S. Public Health Service (5) at Lathrop Wells, about 15 miles southwest of the test cell. We then decided to proceed with the recovery and processing of samplers as though the test had gone according to plans.

Gamma spectrometry provided no evidence of short-lived fission products in our samples of "fallout" and "aerosol". From this we concluded that the radioactive materials actually collected were not reactor effluents but fallout of tropospheric and/or stratospheric origin, probably produced by nuclear detonation in the U.S.S.R. (2).

Data derived from gross assays of radioactivity seem to indicate a close relationship between local patterns of fallout deposition,

Figure 1. Location of "fallout" and "aerosol" sampling stations and sectors. Clark Road: 10 stations at intervals of 0.6 mi., 2 stations per sector; Lathrop Wells: 20 stations at intervals of 0.4 mi., 4 stations per sector; Death Valley Jct.: 15 stations at intervals of 0.8 mi., 3 stations per sector.

topography, and meteorological conditions. Corcos (1) has described the probable influence of surface wind patterns and topographic obstacles on the "non-homogeneity" of fallout deposition. This paper deals with the probable influence of temperature inversions and cold air drainage on local fallout deposition.

PROCEDURES

About 10:00 a.m. on the morning of December 7th, granular fallout collectors and cheesecloth aerosol collectors were prelocated along roads (Fig. 1) which approximate arcs of 5, 16, and 37 miles to the southwest and south of the reactor test cell in Area 400 at the Nevada Test Site. These were recovered about 24 hours later.

Each of the three roads along which collectors were located extends from west to east across a valley or part of a valley. While elevations were not measured in the field, it is apparent from the location of topographic contours that the western and eastern sectors of the Clark Road and Lathrop Wells transects are higher than their central sectors. The western half of the transect through Death Valley Junction is above 2000 ft. and the eastern half crosses a valley which lies below 2000 ft. elevation.

Granular fallout collectors consisting of polyethylene pellets spread on a mylar film in a shallow pan were used to collect particulate materials deposited on horizontal surfaces. These collectors and the methods used in separating particle-size fractions have been described by Romney (4). The only particle-size fractions considered in this study were $>44\mu$ and $<44\mu$ diameter.

Samples recovered from the granular fallout collectors were placed on filter paper in 55 mm plastic dishes and assayed for gross beta activity. The apparatus used for this purpose was a halogen-filled Anton tube in conjunction with a Nuclear Chicago Model 183 scaler. The Anton tube was mounted in a 2" lead shield lined with aluminum foil. Counting efficiency, based on a $\text{Sr}^{90}\text{-Y}^{90}$ standard having the same geometry as the samples, was approximately 10%; and the " d/m/ft^2 " values given in Table I were calculated on the basis of this factor. Except for a few low-activity samples, counting errors were less than 10%.

The "cheesecloth aerosol collector" (Fig. 2) was designed to collect radioactive materials deposited on vertical surfaces. It consists of an open-ended, equilateral prism (12" x 12") composed of hardware cloth covered with a piece of ordinary cheesecloth (ca. 100 threads per inch) measuring 12" x 36".

In order to estimate differences in deposition above and below discontinuous shrub canopies having an average height of about 3 ft., two of these samplers were mounted on a steel fence post at each station. One was placed at the top of the post (ca. 5-6 ft. above the ground) and the other near the bottom (ca. 0.5-1.5 ft. above the ground). Both were held in place by C-clamps.

After exposure, the cheesecloth was carefully removed from the wire frame and folded into a metal salve box (1" deep x 3" diameter).

Gross gamma assays were made with a 3" NaI (Th) crystal in conjunction with a Nuclear Chicago Model 183B scaler. The crystal

Table I Summary of gross beta activity deposited on granular "fallout" collectors and of gross gamma activity deposited on cheesecloth "aerosol" collectors during the night of December 7-8, 1961

"FALLOUT": beta activity in "d/m/ft²" of horizontal surface based on a Sr⁹⁰-Y⁹⁰ standard (1)

ARC:			CLARK ROAD			LATHROP WELLS			DEATH VALLEY JCT.		
Sector	Particle-Size		Sector	Particle-Size		Sector	Particle-Size		Sector	Particle-Size	
(2)	44μ	44μ	Means:	44μ	44μ	Means:	44μ	44μ	Means:	44μ	44μ
A	57	161	218	15	400	415	26	271	297		
B	22	227	249	15	539	554	15	310	325		
C	22	185	207	29	372	401	24	178	202		
D	26	158	184	29	284	313	9	75	83		
E	22	242	264	42	361	403	7	101	108		
Average:	30	195	225	29	391	420	16	187	203		

"AEROSOL": gamma activity in "d/m/ft²" of vertical surface based on a Cs-137 standard. (3)

ARC:			CLARK ROAD			LATHROP WELLS		
Sector	Ht. of Sampler		Sector	Ht. of Sampler		Sector	Ht. of Sampler	
(2)	.5-1.5;	5-6 ft.	Means:	.5-1.5;	5-6 ft.	Means:	.5-1.5;	5-6 ft.
A	455	1454	954	2792	3432	3107		
B	414	937	675	1833	2906	2369		
C	471	772	621	1181	3073	2127		
D	484	1355	919	1626	2622	2124		
E	1445	2407	1926	3038	3549	3293		
Average:	654	1385	1019	2094	3115	2604		

- (1) At time of counting: Clark Road & Lathrop Wells, December 18-22, 1961; Death Valley Jct., January 3, 1962.
- (2) Stations per sector (Fig. 1): Clark Road, 2; Lathrop Wells, 4; Death Valley Jct., 3.
- (3) At time of counting: December 12-13, 1961.

Figure 2. Cheesecloth aerosol collector. The prismoidal frame (A) is made of 1/4" hardware cloth 12" x 36". In use (B), the frame is covered by ordinary cheesecloth (100 threads per inch) and mounted on a metal fencepost.

was placed in a lead-brick shield, and the salve boxes containing cheesecloths were placed on the crystal. The counting efficiency of this system, based on a Cs^{137} standard (solution added to new cheesecloth in a salve box) was 2.6%; and the "d/m/ft²" values in Table I were calculated on the basis of this factor. Counting errors were less than 5%.

Gross gamma spectra were obtained for the samples recovered from the east end of Clark Road. The multi-channel analyzer used for this purpose was being repaired at the time and was operable only to a limited degree. The energy measurements (MeV) were correct, but calibration of the vertical axis (c/m/channel) was not deemed feasible.

RESULTS

The average gross beta activity (Table I) of material recovered from granular fallout collectors on the Lathrop Wells transect (420 d/m/ft²) was higher than that of samples from the Clark Road (225 d/m/ft²) and Death Valley Junction (203 d/m/ft²) transects. The major part of the activity was associated with particles <44 μ diameter. The average gross gamma activity deposited on cheesecloth aerosol collectors on the Lathrop Wells transect was considerably higher than the average for Clark Road. In both areas, there was significantly more activity on the cloths exposed 5-6 ft. above ground than on those exposed 0.5-1.5 ft. above ground. (N.B. Since little or no deposition was expected on the inside surfaces of cheesecloth collectors, the surface area of each cloth was considered to be 3 ft² instead of 6 ft².)

The west to east variation of radioactivity deposited on granular fallout collectors and on cheesecloth aerosol collectors is illustrated in Figure 3. In all cases, the values for sectors A and B are higher than those for C and D; and the values for sector E are higher than those for sector D. It is generally evident that less activity was deposited in areas of lower elevation, relatively more in areas of higher elevation.

The gross gamma spectra of samples collected at the east end of Clark Road are illustrated in Figure 4. The spectrum for particles $<44\mu$ diameter exhibits no pronounced energy peaks. The spectra for the two cheesecloths and for particles $>44\mu$ clearly indicate the presence of Ce^{144} , Ru^{106} , and Zr-Nb^{95} .

DISCUSSION

At the time of the reactor test (2:15 p.m., December 7, 1961) winds from the surface to 4000 ft. above the surface in the vicinity of the reactor test cell were light and variable with a mean azimuth of about 250° . There was an inversion layer between 2000 and 3500 ft. above the surface. During the first two hours after its release, the effluent cloud was tracked by an aerial survey crew for about 18 miles to the northeast of the test cell, but ground monitors directly under the cloud detected no increase of radiation above background. According to the report of the U. S. Public Health Service (5) --

"Air samples collected during the afternoon and early evening of December 7 at the CP, Frenchman Flat, and the Transmitter Farm contained levels of gross beta activity usually observed in these locations, but samples collected at these stations during the following night contained ten times the usual level of gross beta activity. During that night, traces of fresh fission products also reached Lathrop

Figure 3. Average beta activity of material deposited on granular "fallout" collectors and average gamma activity of material deposited on cheesecloth "aerosol" collectors in relation to location on roads (Fig. 1) which cross valleys.

Figure 4. Gross gamma spectra of material deposited December 7-8, 1961 on granular "fallout" collectors (A and B) and on cheesecloth "aerosol" collectors (C and D) at the east end (Fig. 1) of Clark Road.

Wells, Groom Lake, and Indian Springs. This ubiquitous distribution evidently occurred after the break-up of the inversion condition between 2000' and 3500' above ground level in which the radioactive material had been trapped.

With the KIWI effluent in this layer there was probably a build-up of older nuclear debris which would account for the slightly increased levels of gross beta activity observed in air samples from several other locations."

The same report (5) provides evidence that the effluent from Kiwi B-1a contained significant quantities of Sr^{91} , I^{131} , Te^{132} , I^{135} , and Xe^{135} . The gamma emitters indicated in Figure 4 are Ce^{144} , Ru^{106} , and Zr-Nb^{95} . At the time our assays were made (late December) the short-lived radio-nuclides reported by the U.S.P.H.S. were not present in detectable quantities; and it seems quite probable that the longer-lived radio-nuclides which were detected were not produced by the reactor. They may have been produced by nuclear detonations in the U.S.S.R. (2) and transported via the troposphere and/or stratosphere to southern Nevada.

In attempting to explain the observed patterns of "fallout" and "aerosol" deposition (Fig. 3) in relation to topography, it may help to reconstruct the events of December 7th and 8th. During the late morning and early afternoon of the 7th, tropospheric and/or stratospheric fallout, presumed to be of Russian origin, accumulated in an inversion layer 2000-3500 ft. above the ground. This material, along with the trapped reactor effluent, was not released until about sunset when the inversion layer was disrupted.

At about the same time, nocturnal cooling and cold air drainage resulted in the development of local inversions close to the ground,

especially in valleys and depressions, as described by Geiger (3). Some of the material falling from the disrupted inversion layer 2000-3500 ft. above ground, was then trapped in valley inversion layers much closer to the ground. Samplers located at higher elevations were above the valley inversion layer and thus collected more radioactive "fallout" and "aerosol" than samplers located at lower elevations, i.e., below the valley inversions.

The apparent "hot-spot" in the vicinity of Lathrop Wells could have resulted from the southward (down-slope) drainage of cold air from Jackass Flat (the area below 4000 ft. elevation and north of U. S. highway 95) and from the more extensive upland area which probably drains through Forty-Mile Canyon. The deposition of considerably more radioactive material on cheesecloth collectors exposed 5-6 ft. above ground than on similar collectors exposed 0.5-1.5 ft. above ground could have been due to a higher average wind velocity (1, 3) at the higher level above ground.

In the absence of meteorological data to confirm the supposition of valley inversions and cold air drainage, this explanation must be regarded as a speculative hypothesis; but it seems to fit the facts, currently available. Further studies of the influence of topography and local meteorological conditions on the deposition of particulate fallout and radioactive aerosols might provide information which would help explain the local variability of environmental contamination due to the deposition of reactor effluents and/or the deposition of fallout from nuclear detonations.

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