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EXPOSED TO FALLOUT RAIN
AND A COMPARISON TO A SIMILAR
CONTROL POPULATION**

Hiroaki Yamada
T. D. Jones



OAK RIDGE NATIONAL LABORATORY
OPERATED BY UNION CARBIDE CORPORATION • FOR THE U.S. ATOMIC ENERGY COMMISSION

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ABSTRACT

Since about 1947 it has been thought that "A-bomb" survivors in Hiroshima and Nagasaki who had experienced the fallout rains and yet displayed no beta-ray burns on the upper convex portions of their anatomies probably did not receive significant levels of exposure from fallout; however, evidence collected by the Atomic Bomb Casualty Commission's survivor observation program tends to indicate the contrary. This paper is an examination of readily available information and represents an attempt to establish conclusions which would either promote or discourage more detailed analyses of the effects of radiation fallout on an otherwise lightly exposed population.

BACKGROUND AND OBJECTIVE

The Atomic Bomb Casualty Commission (ABCC) in Hiroshima and Nagasaki has studied most latent and late radiation-inducible effects through an extensive patient observation and diagnostic program established in 1947. These studies of delayed radiation-inducible^b effects have been thorough and well documented,⁽¹⁻³⁾ because the ABCC, by limiting its mission to the detailed study of delayed radiation effects, has concentrated its effort in these areas. The reasons for this limitation are fairly obvious and will not be discussed here. A broadly based dosimetric program established by the Oak Ridge National Laboratory (ORNL) and independently, but on a more limited basis, by the Japanese National Institute of Radiological Sciences (NIRS) has provided techniques^(4,5) for the accurate prediction of exposure levels^c for most

^aConsultant on loan from Atomic Bomb Casualty Commission, Hiroshima, Japan.

^bRadiation-inducible effects apply to those effects having higher-than-normal occurrence probabilities.

^cExposure levels in this report refer to the amount of initial radiation only, and no numerical assessments of "black" rain exposure levels are attempted.

survivors exposed to "initial" radiation from the bombs. Survivors may also have been irradiated by (a) lingering in the induced-activity region near the hypocenter and/or (b) being in one of the several outlying districts where the "black" fallout rain was experienced. In the past, the levels of these exposures were thought to have been extremely low and, thus, second-order contributors to doses of most individuals. Arakawa⁽⁶⁾ has calculated the maximum "possible" (not probable) exposure due to induced activity near the hypocenter, and although this exposure value was low, it is still probably unrealistically high in its estimation of the "probable" exposure from induced activity. It seems unlikely that people in outlying districts immediately migrated towards the hypocenters of the bombs and stayed there during the resulting fires. The "black" rain problem has been considered only on a macroscopic scale and has usually been assumed, perhaps prematurely, to be a second-order effect. The "black" rain fell on some outlying provinces in irregularly shaped patterns and generally on people who were exposed to unimpressively low levels of initial radiation so that the fallout rain was the primary mode of exposure in most cases.

It was expected that particulates from the fallout rain would be removed quickly from the skin and clothing of those survivors experiencing precipitation heavier than a moderate sprinkle or a light drizzle; however, anomalies have been observed which seem contrary to this assumption. Instead, some of the particulates deposited by light precipitation may have been washed into and captured by the hair and clothing where they could have become an important contributor to the dose of an individual survivor; however, it seemed that "black" rain dose levels were extremely low for those survivors not experiencing beta-ray burns^d on the upper convex portions of their bodies. Evidence from several ABCC medical observation histories now casts considerable doubt on the accuracy of this assumption.

^dIn fission product decay, a beta particle is liberated in each act of radioactive disintegration. Photons are produced in about one-half of the fission product decays; however, the fraction varies with time. The photons have greater penetrating power and contribute more to the radiation "insult" of an internal biological organ, and the beta burns are used as a crude biological dosimeter.

SELECTION OF SURVIVORS EXPOSED TO "BLACK" RAIN

ORNL has microfilm copies of 11,915 shielding histories for Hiroshima survivors and 2046 histories for Nagasaki survivors. All survivors who were more than 1600 meters from the hypocenter at the time of initial exposure (ATE) and experienced any degree of fallout rain (222 in Hiroshima) were selected from this set of shielding histories. Since it was highly desirable to have as many "black" rain survivors as possible, 65 additional cases were found in an ABCC computer listing. For Nagasaki, only 82 cases were found in an ABCC computer listing, and no cases were selected from the microfilm, because all of these histories were for survivors protected by heavy shielding structures.

The data for the fallout rain survivors were coded and then punched on IBM cards in order to simplify the mechanics of the study. A summary of the fallout rain coding procedure is presented below.

<u>Item No.</u>	<u>Description of Coded Parameter</u>	<u>Columns^e</u>	<u>No. of Columns</u>
1	Master File Number (MFN)	1-6	6
2	Location of the Fallout Rain ^f		
	Abscissa	7-8	2
	Ordinate	9-10	2
3	Data on Rain and Particulates		
	A.	11	1
	<u>Code</u> <u>Intensity of Rain</u>		
	1 Sprinkle		
	2 Drizzle		
	3 Shower		

^e Location of data in the individual tape record of a specific survivor

^f Maps used to read co-ordinates were Army Map Service, U. S. Army, Washington, D. C., Hiroshima-AMS L902 138449 9-46 1946. The co-ordinate notation xxxx.xx is usually abbreviated to xx.xx by the omission of the first two digits, but in this report it was coded as x.x with three digits omitted. For example, 1302.54 was coded as 2.5.

<u>Item No.</u>	<u>Description of Coded Parameter</u>	<u>Columns</u>	<u>No. of Columns</u>
3	A. (cont'd)		
	<u>Code</u> <u>Intensity of Rain</u>		
	4 Thunderstorm		
	7 No information ^g		
	9 Unknown		
	B.	12	1
	<u>Code</u> <u>Condition of Rain</u>		
	1 Muddy		
	2 Pitch		
	3 Oilish		
	7 No information		
	9 Unknown		
	C.	13	1
	<u>Code</u> <u>Particulate Content of Rain</u>		
	1 Black		
	2 Dark		
	3 Clear		
	7 No information		
	9 Unknown		
	D.	14	1
	<u>Code</u> <u>Size of Drops</u>		
	1 Large		
	2 Medium		
	3 Small		
	7 No information		
	9 Unknown		
4	Onset of Rain	15	1
	<u>Code</u> <u>Time of Onset</u>		
	1 < 30 minutes after ATE		
	2 30- < 60 minutes after ATE		
	3 60- < 120 minutes after ATE		
	4 120- < 180 minutes after ATE		
	5 180- < 240 minutes after ATE		
	6 More than above		
	7 No information		
	9 Unknown		

^gNo information appears several places in this report; it means that conditions were met but documentation was insufficient.

<u>Item No.</u>	<u>Description of Coded Parameter</u>		<u>Columns</u>	<u>No. of Columns</u>
5	Duration of Rain		16	1
	<u>Code</u>	<u>Duration</u>		
	1	< 10 minutes		
	2	10- < 30 minutes		
	3	30- < 60 minutes		
	4	60- < 90 minutes		
	5	90- < 120 minutes		
	6	2-3 hours		
	7	No information		
	8	More than 3 hours		
	9	Unknown		
6	Clothing on Head of Survivor		17	1
	<u>Code</u>	<u>Clothing</u>		
	1	None		
	2	Air-raid hood		
	3	Cap		
	4	Straw hat		
	5	Other than above		
	7	No information		
	9	Unknown		
7	Source of Information		18	1
	<u>Code</u>	<u>Source</u>		
	1	Microfilm		
	2	ABCC list		
	3	Other than above		

SELECTION OF SURVIVORS IN CONTROL GROUP

The total number of selected survivors exposed to fallout rain in Hiroshima was so small (287) that it was not statistically possible to analyze the deviations of the exposure situation according to type and amount of clothing and intensity and particulate content of the fallout rain, but tabulations corresponding to these classifications are shown in Tables 1, 4, and 5. ORNL has copies of ABCC magnetic tape records for 75,100 survivors in Hiroshima and 24,900 survivors in Nagasaki. The control population, chosen from these magnetic tape records, was selected from similar outlying districts which did not experience fallout rain but were subjected to similar levels of

initial radiation. The control area, in the southeast portion of Hiroshima, was chosen on the following bases:

1. Co-ordinates

$$4500 < \text{Abscissa} < 5000$$

$$5600 < \text{Ordinate} < 6100$$

2. Exposure distance

$$> 1600 \text{ meters from the hypocenter}$$

Tabulations of the effects of radiation on the "black" rain survivors and on the control population are shown in Tables 2, 3, 6, 7, 8, and 9.

Table 1. Classification of Survivors According to Characteristics of "Black" Rain

Description of Rain	Hiroshima		Nagasaki	
	Hiroshima	Nagasaki	Hiroshima	Nagasaki
Intensity			Onset of Fallout Rain	
Sprinkle	23	1	< 30 minutes	12
Drizzle	4	32	30- < 60 minutes	23
Shower	34	7	60- < 120 minutes	43
Thunderstorm	99	0	120- < 180 minutes	21
No information	119	31	180- < 240 minutes	10
Unknown	8	11	> 240 minutes	10
Condition			No information	155
Muddy	2	0	Unknown	13
Pitch	3	0	Duration of Rain	
Oilish	19	3	< 10 minutes	69
No information	255	65	10- < 30 minutes	57
Unknown	8	14	30- < 60 minutes	28
Particulate Content			60- < 90 minutes	9
Black	106	8	90- < 120 minutes	26
Dark	11	0	2-3 hours	6
Clear	8	3	> 3 hours	1
No information	150	55	No information	76
Unknown	12	16	Unknown	15
Size of Drops			Clothing on Head	
Large	137	14	None	124
Medium	1	7	Air raid hood	2
Small	7	1	Cap	6
No information	134	48	Straw hat	1
Unknown	8	12	Other than above	27
			No information	123
			Unknown	4
			Source of Information	
			Microfilm	222
			ABCC list	65

(Note: At this stage, Nagasaki data were assumed to be insufficient, and the study was continued for Hiroshima only.)

Table 2. Specific Radiation Symptoms^g versus Initial Exposure
for "Black" Rain Survivors

Initial Exposure ^h	Number of Survivors	
< 1 rad	74	
1-10 rads	121	
10-20 rads	41	
<hr/>		
Minor Symptoms	Number of Survivors	
Fever		
Occurred within 21 days	32	(13.56%)
Occurred within 22-60 days	15	(6.35%)
Other ⁱ (includes non-occurrence of symptom)	189	
Vomiting		
Occurred within 21 days	18	(7.62%)
Occurred within 22-60 days	4	(1.70%)
Other (includes non-occurrence of symptom)	214	
Diarrhea (nonbloody)		
Occurred within 21 days	39	(16.53%)
Occurred within 22-60 days	12	(5.08%)
Other (includes non-occurrence of symptom)	185	
Diarrhea (bloody)		
Occurred within 21 days	13	(5.51%)
Occurred within 22-60 days	7	(2.97%)
Other (includes non-occurrence of symptom)	216	

^gIt seems as if most survivors experiencing one or more major radiation symptoms also should have experienced one or more minor radiation symptoms; however, this anomaly does not seem to be borne out by the records. These apparent artifacts may have been caused by a variety of reasons, viz., (1) major symptoms may have distracted the survivor's attention so that he did not recognize the minor symptoms; (2) the interviewer may not have recorded minor symptoms if major symptoms were present; and (3) some minor symptoms may actually have a higher response threshold than that of many of the major symptoms. In the "black" rain study group of 236 survivors from the control population of 16,045 cases were listed as having both major and minor symptoms.

^hThis study included 236 individuals. "Black" rain cases in which the survivor was exposed to more than 20 rads of initial radiation were not studied in detail, because the 16,045 control cases did not include any exposures to more than 20 rads of initial radiation.

ⁱSymptom occurred but insufficient data for date of onset, duration, etc.

Table 2. Specific Radiation Symptoms versus Initial Exposure
for "Black" Rain Survivors (cont'd)

Major Symptoms	Number of Survivors	
<u>Oropharyngeal Lesions</u>		
Sore throat		
occurred within 21 days	13	(5.51%)
occurred within 22-60 days	3	(1.27%)
other (includes non-occurrence of symptoms and/or questionable)	220	
Sore mouth		
occurred within 21 days	10	(4.24%)
occurred within 22-60 days	2	(0.85%)
other (includes non-occurrence of symptoms and/or questionable)	224	
Sore gums		
occurred within 21 days	5	(2.12%)
occurred within 22-60 days	3	(1.27%)
other (includes non-occurrence of symptoms and/or questionable)	228	
<u>Purpura</u>		
Gingival bleeding		
occurred within 21 days	11	(4.66%)
occurred within 22-60 days	4	(1.69%)
other (includes non-occurrence of symptoms and/or questionable)	221	
Purpura		
occurred within 21 days	7	(2.97%)
occurred within 22-60 days	3	(1.27%)
other (includes non-occurrence of symptoms and/or questionable)	226	
Other bleeding		
occurred within 21 days	1	(0.42%)
occurred within 22-60 days	0	
other (includes non-occurrence of symptoms and/or questionable)	235	
<u>Nonpurpuric Bleeding</u>		
Occurred within 21 days	11	(4.66%)
Occurred within 22-60 days	1	(0.42%)
Other (includes non-occurrence of symptoms and/or questionable)	224	
<u>Epilation</u>		
Slight (less than 1/4)	142	(60.17%)
Moderate (1/4 to 3/4)	13	(5.51%)
Severe (more than 3/4)	2	(0.85%)
Present, but degree, date of onset unknown	5	(2.11%)
Other (includes non-occurrence of epilation and/or questionable)	74	

Table 3. Relationship between Initial Exposure and Type of Radiation Symptoms^j
for 287 "Black" Rain Survivors

Initial Exposure	Incidence of Radiation Symptoms	
< 1 rad	74	(25.8%)
Minor symptoms ^k	1	(0.3%)
Major symptoms ^k	54	(18.8%)
Minor and major symptoms	16	(5.6%)
No symptoms	28	(9.8%)
1 to 10 rads	121	(43.2%)
Minor symptoms	1	(0.3%)
Major symptoms	54	(18.8%)
Minor and major symptoms	29	(10.1%)
No symptoms	37	(12.9%)
10 to 20 rads	41	(14.3%)
Minor symptoms	1	(0.3%)
Major symptoms	15	(5.2%)
Minor and major symptoms	15	(5.2%)
No symptoms	10	(3.5%)
> 20 rads ^l	51	(17.8%)
Minor symptoms	0	
Major symptoms	16	(5.6%)
Minor and major symptoms	30	(10.5%)
No symptoms	5	(1.7%)

^jThis report ignores synergistic effects and makes no attempt to distinguish whether "radiation sicknesses" were from external sources, inhaled microscopic radioactive particles, or even radioactive particles ingested through food and drink. It is possible that individual excitement levels may have influenced vomiting and nonbloody diarrhea; however, control survivors were carefully selected so that they were subjected to all other forms of trauma except for exposure to the fallout rain.

^kMinor symptoms include fever, vomiting, and bloody and nonbloody diarrhea. Major symptoms include all other radiation-induced abnormalities, e.g., oropharyngeal lesions, purpura, epilation, etc.

^l"Black" rain cases which included exposure to more than 20 rads of initial radiation were not studied in detail except in this table, because the 16,045 control cases did not include any who were exposed to more than 20 rads of initial radiation.

Table 4. Type of Radiation Symptoms versus Intensity of Rain

Initial Exposure	Radiation Symptoms	Intensity of Rain				No information and/or Questionable	Total
		Sprinkle	Drizzle	Shower	Thunderstorm		
< 1 rad	Minor only	0	0	0	0	1	1
	Minor and major	3	0	6	3	4	16
	Major only	1	0	4	10	14	29
1-10 rads	Minor only	0	0	1	1	0	2
	Minor and major	0	0	3	12	16	31
	Major only	3	2	8	17	24	54
10-20 rads	Minor only	0	0	0	0	1	1
	Minor and major	0	0	0	3	11	14
	Major only	3	0	0	1	11	15
TOTAL		10	2	22	47	82	163

Table 5. Intensity of Rain versus Duration of Rain

Intensity of Rain	Duration					No information or Unknown	Total
	< 10 minutes	10-30 minutes	30-60 minutes	60-120 minutes	> 2 hours		
Sprinkle	14	3	0	0	0	6	23
Drizzle	2	0	2	0	0	0	4
Shower	10	7	10	4	0	3	34
Thunderstorm	18	24	12	21	5	19	99
No information or unknown	26	23	4	8	2	64	127
TOTAL	70	57	28	33	7	92	287

Table 6. Summary of Type of Radiation Symptoms for the "Black" Rain Survivors

Number of Symptoms	Initial Exposure						Total
	< 1 rad		1-10 rads		10-20 rads		
Minor							
1	10	(4.2%)	12	(5.1%)	9	(3.8%)	31 (13.1%)
2	4	(1.7%)	15	(6.4%)	7	(3.0%)	26 (11.0%)
3	3	(1.3%)	3	(1.3%)	0		6 (2.5%)
4	0		0		0		0
Total	17	(7.2%)	30	(12.7%)	16	(6.8%)	63 (26.7%)
Major							
1	33	(14.0%)	70	(29.7%)	27	(11.4%)	130 (55.1%)
2	9	(3.8%)	8	(3.4%)	1	(0.4%)	18 (7.6%)
3	3	(1.3%)	3	(1.3%)	1	(0.4%)	7 (3.0%)
4	0		2	(0.8%)	1	(0.4%)	3 (1.3%)
Total	45	(19.1%)	83	(35.2%)	30	(12.7%)	158 (66.9%)
Type of Symptoms							
Minor only	1	(0.4%)	1	(0.4%)	1	(0.4%)	3 (1.3%)
Major only	29	(12.3%)	54	(22.9%)	15	(6.4%)	98 (41.5%)
Minor and major	16	(6.8%)	29	(12.3%)	15	(6.4%)	60 (25.4%)
None	28	(11.9%)	37	(15.7%)	10	(4.2%)	75 (31.8%)
Total	74	(31.4%)	121	(51.3%)	41	(17.4%)	236 (100.0%)

Table 7. Specific Radiation Symptoms versus Initial Exposure
for the Control Population

Initial Exposure	Number of Survivors	
< 1 rad	13,110	(81.71%)
1-10 rads	2,144	(13.36%)
10-20 rads	791	(4.93%)
> 20 rads	0	

Minor Symptoms	Number of Survivors	
Fever		
Occurred within 21 days	212	(1.32%)
Occurred within 22-60 days	65	(0.40%)
Other (includes non-occurrence of symptom and/or questionable)	15,769	
Vomiting		
Occurred within 21 days	88	(0.55%)
Occurred within 22-60 days	14	(0.09%)
Other (includes non-occurrence of symptom and/or questionable)	15,943	
Diarrhea (nonbloody)		
Occurred within 21 days	122	(0.76%)
Occurred within 22-60 days	53	(0.33%)
Other (includes non-occurrence of symptom and/or questionable)	15,870	
Diarrhea (bloody)		
Occurred within 21 days	37	(0.23%)
Occurred within 22-60 days	18	(0.11%)
Other (includes non-occurrence of symptom and/or questionable)	15,990	

Major Symptoms	Number of Survivors	
Oropharyngeal Lesions		
Sore throat		
occurred within 21 days	21	(0.13%)
occurred within 22-60 days	7	(0.04%)
other (includes non-occurrence of symptom and/or questionable)	16,017	

Table 7. Specific Radiation Symptoms versus Initial Exposure
for the Control Population (cont'd)

Major Symptoms	Number of Survivors	
Sore mouth		
occurred within 21 days	14	(0.09%)
occurred within 22-60 days	7	(0.04%)
other (includes non-occurrence of symptom and/or questionable)	16,024	
Sore gums		
occurred within 21 days	7	(0.04%)
occurred within 22-60 days	9	(0.06%)
other (includes non-occurrence of symptom and/or questionable)	16,029	
<u>Purpura</u>		
Gingival bleeding		
occurred within 21 days	25	(0.16%)
occurred within 22-60 days	14	(0.09%)
other (includes non-occurrence of symptom and/or questionable)	16,006	
Purpura		
occurred within 21 days	14	(0.09%)
occurred within 22-60 days	18	(0.11%)
other (includes non-occurrence of symptom and/or questionable)	16,013	
Other bleeding		
occurred within 21 days	1	(0.01%)
occurred within 22-60 days	5	(0.03%)
other (includes non-occurrence of symptom and/or questionable)	16,039	
<u>Nonpurpuric Bleeding</u>		
Occurred within 21 days	231	(1.44%)
Occurred within 22-60 days	21	(0.13%)
Other (includes non-occurrence of symptom and/or questionable)	15,793	
<u>Epilation</u>		
Slight (less than 1/4)	646	(4.03%)
Moderate (1/4 to 3/4)	47	(0.29%)
Severe (more than 3/4)	20	(0.12%)
Present, but degree, date of onset unknown	12	(0.07%)
Other (includes non-occurrence of symptom and/or questionable)	15,320	

Table 8. Summary of Type of Radiation Symptoms for the Control Population

Number of Symptoms	Initial Exposure			Total
	< 1 rad	1-10 rads	10-20 rads	
Minor				
1	5 (0.03%)	109 (0.68%)	180 (1.12%)	249 (1.83%)
2	2 (0.01%)	42 (0.26%)	76 (0.47%)	120 (0.75%)
3	2 (0.01%)	9 (0.06%)	29 (0.18%)	40 (0.25%)
4	0	1 (0.006%)	4 (0.02%)	5 (0.03%)
Total	9 (0.06%)	161 (1.00%)	289 (1.80%)	459 (2.86%)
Major				
1	143 (0.9%)	377 (2.3%)	367 (2.3%)	887 (5.5%)
2	1 (0.006%)	30 (0.2%)	50 (0.3%)	81 (0.5%)
3	0	12 (0.1%)	22 (0.1%)	34 (0.2%)
4	0	3 (0.02%)	8 (0.05%)	11 (0.1%)
Total	144 (0.9%)	422 (2.6%)	447 (2.8%)	1013 (6.3%)

Table 9. Comparison of the Symptoms of "Black" Rain Survivors
to Those of the Control Population

Number of Symptoms		Initial Exposure			Total
		< 1 rad	1-10 rads	10-20 rads	
Minor					
1	EP*	10 (4.2%)	12 (5.1%)	9 (3.8%)	31 (13.1%)
	CP**	5 (0.03%)	109 (0.7%)	180 (1.1%)	294 (1.8%)
2	EP	4 (1.7%)	15 (6.4%)	7 (3.0%)	26 (11.0%)
	CP	2 (0.01%)	42 (0.3%)	76 (0.5%)	120 (0.7%)
3	EP	3 (1.3%)	3 (1.3%)	0	6 (2.5%)
	CP	2 (0.01%)	9 (0.06%)	29 (0.2%)	40 (0.2%)
4	EP	0	0	0	0
	CP	0	1 (0.006%)	4 (0.02%)	5 (0.03%)
Total	EP	17 (7.2%)	30 (12.7%)	16 (6.8%)	63 (26.7%)
	CP	9 (0.06%)	161 (1.0%)	289 (1.8%)	459 (2.9%)

Major					
1	EP	33 (14.0%)	70 (29.7%)	27 (11.4%)	130 (55.1%)
	CP	143 (0.9%)	377 (2.3%)	367 (2.3%)	887 (5.5%)
2	EP	9 (3.8%)	8 (3.4%)	1 (0.4%)	18 (7.6%)
	CP	1 (0.006%)	30 (0.2%)	50 (0.3%)	81 (0.5%)
3	EP	3 (1.3%)	3 (1.3%)	1 (0.4%)	7 (3.0%)
	CP	0	12 (0.07%)	22 (0.1%)	34 (0.2%)
4	EP	0	2 (0.8%)	1 (0.4%)	3 (1.3%)
	CP	0	3 (0.02%)	8 (0.05%)	11 (0.07%)
Total	EP	45 (19.1%)	83 (35.2%)	30 (12.7%)	158 (66.9%)
	CP	144 (0.9%)	422 (2.6%)	447 (2.8%)	1013 (6.3%)
		* exposed population	** control population		

SUMMARY

In Hiroshima, only 287 survivors are documented as being in the "black" rain at distances corresponding to low exposure levels of initial radiation. The control population was similarly chosen so that survivors were more than 1600 meters from the hypocenter (ATE), except they must not have been in one of the outlying districts subjected to any observable degree of fallout rain. This control population consisted of 16,045 survivors, and none of these were exposed to more than 20 rads of initial radiation; consequently detailed tabulations and analyses were attempted only for those exposed to less than 20 rads of initial radiation, i. e., 236 of the 287 "black" rain survivors. Because the "black" rain population was so small, some of the tables in this report fall short of correlating particulate deposition to "radiation sickness," but these tables may be a revealing source of information in the study of fallout on a specific survivor who has experienced radiation-inducible health abnormalities beyond normal expectation.

Because of the limited number of "black" rain survivors in this study, it is extremely difficult to test the original hypothesis, which may be stated as follows: "It was assumed that the particulate initially deposited by light fallout rain was quickly washed from the survivor's person by subsequent rain and, therefore, fallout rain was a secondary mode of exposure which added little to the radiation insult of any specific survivor."

Because of the small "black" rain population, it is desirable to classify radiation symptoms so as to maximize the size of the subpopulations. This task is somewhat complicated by the fact that some survivors experienced minor symptoms only, some experienced major symptoms only, and some experienced both minor and major symptoms. Rather than try to combine data from these somewhat unparallel subpopulations, the authors tend to believe that the information revealed by this study can best be illustrated by the negative approach of Table 10, in which a comparison is made of the number of survivors in the "black" rain population (EP) and in the control population (CP) who reportedly showed no easily observable response to initial major and/or minor effects.

Table 10. Reported "Non-Incidence" of Initial Radiation Effects

Initial Exposure	EP (287 survivors)	CP (16,045 survivors)
< 1 rad	37.8%	99.0%
1-10 rads	30.6%	96.4%
10-20 rads	24.4%	95.4%
> 20 rads	9.8%	(null set)

From Tables 2 and 7, one can also form the ratios of symptom incidence in those exposed to the "black" rain to symptom incidence in the control population shown in Table 11.

Table 11. Specific Symptom versus Ratio of EP Incidence to CP Incidence

Symptom	EP:CP Incidence
Fever	10
Vomiting	14
Diarrhea	22
Sore Throat	42
Sore Mouth	47
Sore Gums	53
Gingival Bleeding	29
Purpura	33
Epilation	15

Although some of the individual ratios may be unreliable, a definite trend is established; and for fever (13.56% of EP), diarrhea (22.04% of EP), and epilation^m (68.64% of EP), the respective ratios of 10, 22, and 15 should be reasonably accurate.

^mThese manifestations were selected because incidence rates were high enough to include sizable subpopulations of the "black" rain survivors.

If vomiting and nonbloody diarrhea are permitted to be thought of as often being stimulated by excitement or concern, then it becomes obvious that the incidence rates for the effects listed in Table 11 indicate an extremely high beta exposure relative to a significant "probable" photon exposure for "black" rain survivors.

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