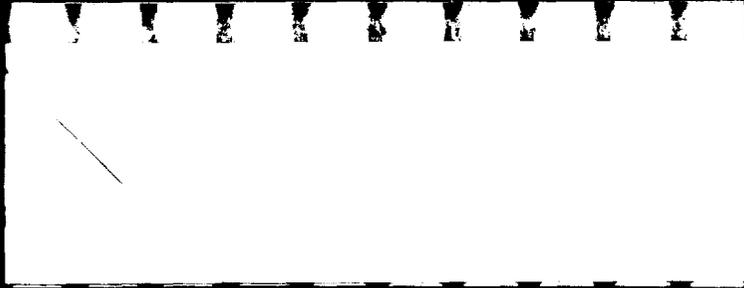


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**RESPONSE TO DCPA QUESTIONS ON FALLOUT**  
**DCPA Research Report No. 20**                      **Nov. 1973**

Prepared by Subcommittee on Fallout  
Advisory Committee on Civil Defense  
National Academy of Sciences  
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SOME ASPECTS OF FALLOUT OF CONCERN TO CIVIL DEFENSE

A report of the ad hoc Subcommittee on Fallout  
Advisory Committee on Civil Defense

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TABLE OF CONTENTS

THE PORTION OF ACTIVITY DEPOSITED IN LOCAL FALLOUT ..... 2

EFFECTS OF SMALL CHANGES IN BURST HEIGHT ON THE  
AMOUNT OF LOCAL FALLOUT ..... 7

EFFECTS OF SOIL TYPE AND BUILDING MATERIAL ON THE  
PORTION OF RADIOACTIVITY DEPOSITED IN LOCAL FALLOUT .....12

THE RADIOIODINE PROBLEM--INHALATION .....16

DETECTION OF FALLOUT BY THE PHYSICAL SENSES .....19

FEASIBILITY OF DEVELOPING FALLOUT PREDICTION TECHNIQUES  
FOR OPERATIONAL APPLICATIONS .....23

RADIOACTIVITY OF CRATERS OF MULTI-MEGATON EXPLOSIONS .....25

INTERACTION OF SIMULTANEOUS SURFACE BURSTS .....27



Some Aspects of Fallout of Concern to Civil Defense

In October 1971, the Research Directorate of the Office of Civil Defense, now the Defense Civil Preparedness Agency (DCPA), posed questions on eight aspects of fallout of interest to civil defense. They were sent to the Fallout Subcommittee of the Advisory Committee on Civil Defense in the form given in Appendix A. These topics encompass problems of the basic constraints used in fallout prediction, various perturbations on the standard surface-burst problem, the direct detection of heavy fallout without instruments, and the feasibility of extrapolating predictions on an operational basis. The Subcommittee itself and working groups of the Subcommittee have attempted to answer questions on these topics, several of which were rephrased in interaction and by agreement with DCPA representatives. The results of these deliberations are the subject matter of this report.

May 1973

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## CHAPTER 1

### THE PORTION OF ACTIVITY DEPOSITED IN LOCAL FALLOUT

A typical deterministic fallout-prediction system is based upon a forecast of climatological winds and a postulated (or calculated) initial distribution of radioactivity on particles of various sizes located at various positions within a radioactive cloud.<sup>1</sup> The amount and kinds of radioactivity postulated depend on the yield of the nuclear explosion, its fission-fusion ratio, the type of fissionable material used, and the kinds of induced activities produced. The height and other dimensions of the cloud depend on the yield and on ambient atmospheric conditions, particularly on the variation of temperature and relative humidity above the ground. During their fall the radioactive particles move laterally under the influence of the wind field. If the above factors are properly accounted for, one can predict levels of deposition of radioactivity on the ground, from which radiation exposure rates can be derived. DCPA and hence this paper is concerned primarily with surface and near-surface bursts. Possibly important perturbations, which will be taken up later, are small changes in the height of burst (Chapter 2), the chemical and physical properties of the soil or other substrate over which the explosion takes place (Chapter 3), and the influence of adjacent, nearly simultaneous bursts (Chapter 8).

A central problem in fallout prediction is that of relating radiation exposure rates at various locations to the yield of the detonation that produced the fallout. Sophisticated models can, at least in principle, rigorously compute this relation nuclide by nuclide for each point on the ground, subject to the accuracy of the fission-product data base, the assumed relation between radioactivity and particle size, and available wind and weather information. Simpler models, however, predict only the gross deposition of mixed-fission products. Any model implies, and one of the models used by DCPA explicitly uses, an empirical factor called the K-factor\* to relate deposition to radiation intensity. In the literature, this term has referred to at least two different but related things: (1) the ratio of exposure rate measured at a particular place in the fallout field to the density of deposition of radioactivity there; and (2) an integrated, weighted average of this ratio over the "local" fallout field. The confusion caused by the various uses of the concept has been well reviewed by Rapp<sup>2</sup> and Cane.<sup>3</sup> The customary unit for K-factors is R/hr per kt/mi<sup>2</sup> at H + 1 hour. Since this is a rather unwieldy unit, we shall not repeat it hereafter.

An idealized limit of the K-factor corresponds to unfractionated fission products uniformly spread over a smooth ideal plane, and measured with an ideal detector 3 feet above the plane. This limit, here called  $K_0$ , varies depending on what particular fission process is being considered. According to Tompkins,<sup>4</sup>  $K_0 = 3067$  for U-235 fissioned by

\*Also called the Normalization Factor, the Magic Number, and the Exposure Rate Conversion Factor.





Problems in using this procedure have been particularly difficult very close to ground zero and very far away from it. At close-in locations, physical factors have often prevented the installation of recording instruments, and high radiation levels have denied entry for standard methods of measurement until decay and weathering have greatly decreased the levels of radiation. Airplane and helicopter measurements over such areas have not been reliable. Often, however, because the area within the innermost measured contour is small, the resultant K-factor has not been sensitive to the estimates needed in lieu of measurements within that contour.

At great distances, the reliability of measurements is reduced because intensities are small, approaching background levels. Unfortunately their contribution to the integral can be large because of the large areas involved. Properly,  $A_1$  (or rather the value of  $I(A_1)$ ) should be determined by the definition of local fallout. The tendency of many investigators to carry out the integration to the limit of reliability of the data results in an implicit definition of local fallout that varies from shot to shot and makes intercomparison of results difficult.

A number of empirical values of  $K_2$  are listed in Table 1. (We cannot guarantee that these data do meet the criterion of consistent integration limits.) All the fallout patterns from which these data were obtained are uncertain to some degree. The Subcommittee believes that the best near-surface-burst data on this list are those from Johnie Boy, Buffalo 2, Zuni, Tewa, and Jangle Surface. Taking a mean of those average values, we get

$$K_2 \approx 1090.$$

This mean represents average field-roughness conditions, and instruments as used in the past. In DCPA use, a K-factor is required which does not include corrections for surface roughness or instrument response, which is to say  $K_1$ . Since  $K_1 = 16/9 K_2$ , the result is

$$K_1 \approx 1930.$$

The Subcommittee recommends that DCPA use this value of  $K_1$ .

TABLE 1. SOME CALCULATED K-VALUES FROM WEAPON TESTS

(Based on field measurements that include terrain roughness effects, and which were not corrected for instrument response.)

Item	Yield kt	Scaled Height of Burst (λ) (ft/kt <sup>1/3</sup> )*	K <sub>2</sub>					Average
			Heffter	Miller	DASA	Tompkins		
Ess	1.2	-61.3		1340	1250			1300
Jangle U	1.2	-16		1710	2170**			1710
Johnie Boy	0.5	- 2.4	1700**	930	1800**	1410		1170
Coulomb C	0.5	0		390	290			340
Buffalo 2		0	880	1080				980
Bravo	15 Mt	0.4	960	610	2080**			785
Zuni	3.53Mt	0.6		1340	960			1150
Tewa	5.01Mt	0.9		900	940			920
Koon	110	2.6		530	725			630
Jangle S	1.2	3.3	1300	1130	1620**			1215
Coulumb B	0.3	4.4	350	250	330			310
Smallboy	low	8.5	480	700***		490		560
Little Feller II	low	10.7	160	450	175	135		230
Little Feller I	low	11.4	190	175	255	133		190
Trinity	19	35		645	740			690
Simon	43	84		360				360
Harry	32	94		520	450			485
Badger	23	103		235	245			240
Nancy	24	104		140	175			155
Annie	16	117		150				150
Humboldt	7.8t	126		415	265			340
Tumbler- Snapper 5	12	129		235				235
Tumbler- Snapper 6	11	133		185	185			185
Met	22	142		155				155
Turk	43	142		235				235

Heffter -- private communication

Miller -- reference 8

DASA -- reference 9

Tompkins-- derived from "fraction down" given in Reference 10. Integrations to 0.5 R/hr except Johnie Boy to 1.0 R/hr.

\* The scaled height of burst (λ) is determined by dividing the actual height of burst in feet by the cube root of the total yield in kilotons.

\*\* Value  $\geq (0.75)^2 \times 2900$ : not included in average.

\*\*\* Reduced from Miller's original 990 by excluding data at distances beyond the 0.5 R/hr contour.

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## CHAPTER 2

### EFFECTS OF SMALL CHANGES IN BURST HEIGHT ON THE AMOUNT OF LOCAL FALLOUT

Data from weapons tests show that radiation-intensity levels of local fallout decrease as the height of burst increases. An estimate of the magnitude of this decrease is of interest to DCPA since detonations in a nuclear attack may occur on contact with urban structures or even in trees. Such heights of burst will, however, be small when scaled from megaton-yield weapons. Taking a one-megaton burst as an example, the scaled height of burst ranges from  $\lambda = 12$  (ft/kt<sup>1/3</sup>)\* for a tall tree or a ten-story building to  $\lambda = 50$  for a 40-story building.

It is well known that the amount of local fallout is very low, almost insignificant, when the height of burst is greater than about a fireball radius, i.e.,  $\lambda = 180^1$ , (except when the burst takes place on a tower.<sup>2,3</sup>). In such detonations, the soil or dust swept up by rising fireball either does not reach the fireball or enters it only after most of the radionuclides have condensed. In this case the small amount of local fallout depends primarily on the mass of the warhead assembly. The bulk of the radionuclides is carried by very small particles which do not fall to the ground fast enough to contribute to local fallout.

For detonations at small heights of burst, the coupling of energy to and the interaction of the fireball with the ground apparently decreases rapidly as the height increases, as manifested in the rapid decrease in crater volume. The particle-size distribution is also shifted to smaller sizes.

In the absence of a theoretical foundation for describing these effects quantitatively, one must take recourse in observation. Table 1 (Chapter 1) lists some K-factors ( $K_2$ ) derived from intensity-area integrals by a number of investigators, with data from bursts beyond the altitude range of immediate concern included for perspective. The averages have been plotted in Figures 1 and 2, along with the spread in various investigators' interpretations. The mode of support of each burst is indicated as a basis for interpretation. Most of these bursts were over dry desert soil at the Nevada Test Site (NTS) and in the low kiloton range. Thus these data are intercomparable. Also shown are K-factors from a number of megaton bursts; although these fallout patterns are much less well known due to the difficulties of obtaining and interpreting data over water, it is comforting to see that their resultant K-factors are consistent with those from NTS shots.

In Figure 2, which extends the field of view to greater heights of burst, the horizontal part of line B represents the mean K-factor

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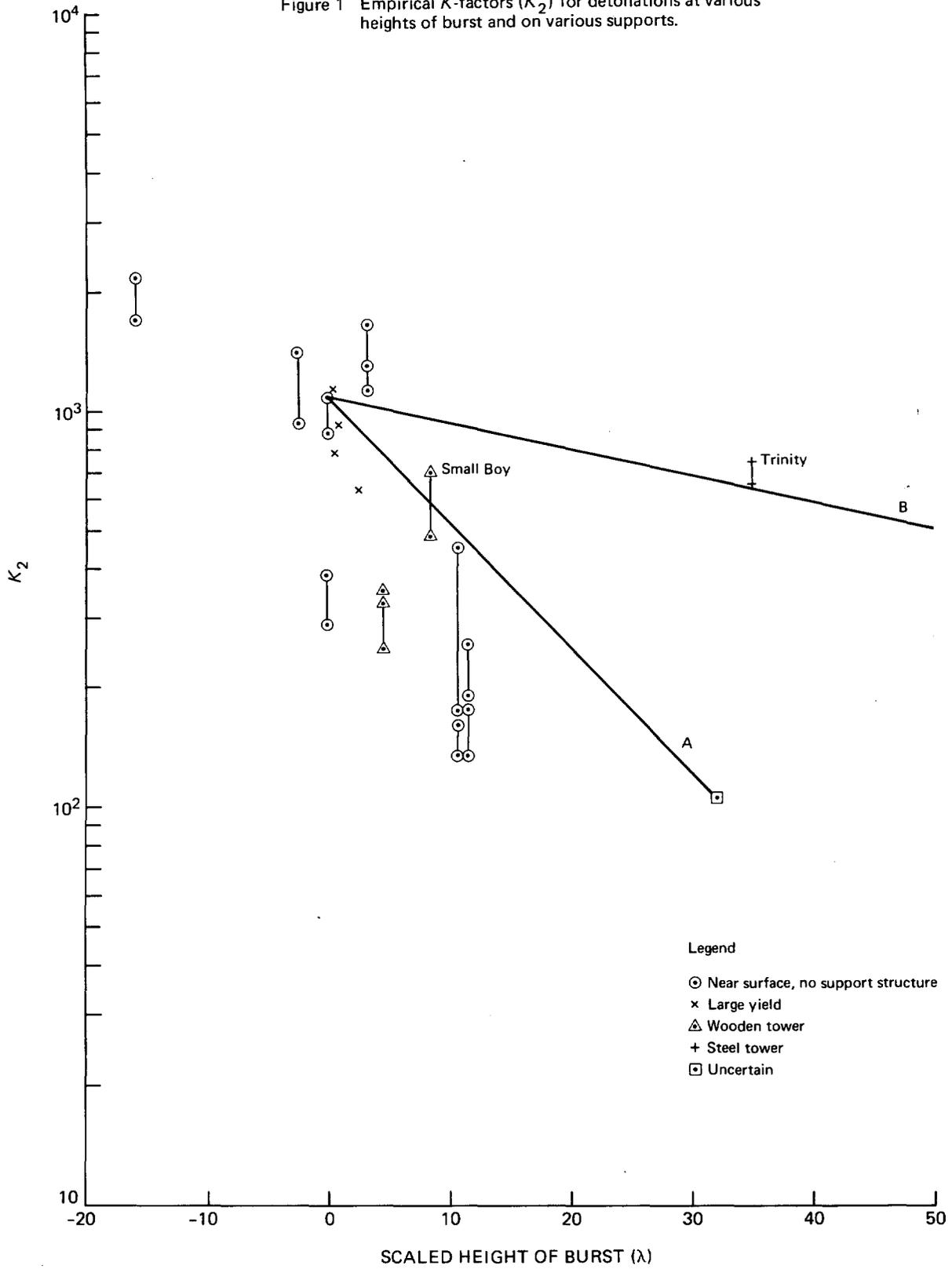
\*See first footnote on Table 1. 7

( $K_2 = 220$ ) for 30 tower shots with  $\lambda \geq 100$ . The horizontal part of line A represents the mean K-factor ( $K_2 = 25$ ) of 40 airbursts. There is a substantial difference between detonations on steel towers and those that are air burst. We consider a burst on a building to be comparable to a burst on a massive steel or concrete tower; similarly a treetop burst is comparable to an airburst. The most critical point for establishing the dependence of K-factor on building height appears to be the Trinity shot, analogous to one megaton on a 30-story building. If wooden towers can be considered analogous to treetop-burst conditions, several points in the two figures are analogous to treetop bursts. The only well-established ones are those for Smallboy and the two Little Fellers. For lower elevations we have Koon, whose suspension does not fit these categories, and Coulomb B, burst on a wooden tower but with a poorly documented fallout pattern.

For air and treetop bursts, the Subcommittee recommends using line A in Figures 1 and 2, which amounts to a factor of about 0.45 for a scaled burst height,  $\lambda$ , of 10. This is uncertain to the extent represented by the spread in the Small Boy data.

As for bursts on buildings, the available data indicate that line B should be used, which is to say a height-of-burst correction of only 0.87 at a scaled height of burst of  $\lambda = 10$ . This effect cannot reduce the K-factor below about 220 no matter how tall the building. As in Chapter 1, DCPA needs a K-factor ( $K_1$ ) that does not reflect reductions for instrument response or ground roughness. On this basis, the minimum K-factor ( $K_1$ ) for bursts on buildings is about 390.

Figure 1 Empirical  $K_2$ -factors ( $K_2$ ) for detonations at various heights of burst and on various supports.







## CHAPTER 3

### EFFECTS OF SOIL TYPE AND BUILDING MATERIAL ON THE PORTION OF RADIOACTIVITY DEPOSITED IN LOCAL FALLOUT

The effects of soil type and building material on the amount and levels of radioactivity deposited in local fallout are of three types: (1) induced activities can enhance the radiation levels over those of fission products alone, and can change the shape of the decay curve; (2) the substrate material can influence fractionation effects among the fission products through variation of melting and vaporization temperatures and chemical reactivity with the various radionuclides; and (3) differences in particle size, density, and other physical properties of the soil or matrix material can influence specific activity/particle-size distributions and hence fall-rate variables.

U. S. experience and hence data are limited to three substrates: Nevada dry desert alluvium, wet coral rock and sand, and sea water. In addition there is the experience with tower bursts (mostly steel, but occasionally of aluminum or wood) referred to in Chapter 2. Comparative analyses of the data are difficult because detonations on coral have generally been larger in yield than those over Nevada soil; the larger yield detonations were also in tropical atmospheres having much higher humidity and other differences from temperate-zone atmospheres.

Extensive work in the days of atmospheric testing<sup>1-5</sup> indicated that the principal soil constituents that influence the production of induced activities are sodium, aluminum, iron, and manganese contained in the soil (these being the principal elements activated by bomb neutrons), and the water content of the soil (a non-activated competitor for neutrons). The longer-lived of the first two induced activities, Na-24, has a half life of only 15 hours, so it significantly affects decay only up to about 4 days after the detonation. It has, however, a penetrating component of radiation that makes its presence important while it does last. At later times, Fe-59 and Mn-54 may be found in relatively large amounts in fallout from large-yield detonations. In general, soil-activation products are not important contributors to local fallout except for weapons with very low fission-fusion ratios.

With respect to the effects of soil type or substrate, no definitive sets of data are available for comparing gross radioactivity/particle-size distributions of the fallout from comparable detonations on dry desert soil and wet coral. In principle, the fallout from detonations over deep water or over wet substrates such as coral should have a smaller K-factor ( $K_2$ ) than fallout from detonations on dry soil, since the radionuclides would be carried initially by smaller particles and by particles with variable fall rates due to evaporation and condensation

of water. However, as Table 2 shows, there is insufficient evidence from the test program to support a conclusion concerning how K-factors vary with depth of water.

A similar effect should result from detonations over very hard substrates such as rock because of the tendency toward the production of smaller particles, with, perhaps, higher specific activities. The crater volume from a near-surface detonation is not considered a good indicator of the value of  $K_2$ , although both crater volume and  $K_2$  decrease (and the average specific activity increases) with increased height of burst.

Under these circumstances, the Subcommittee recommends that DCPA assume for all practical purposes that no soil or substrate effect exists. If there is such an effect, the common soils in the country, being wetter than dry desert alluvium, should yield slightly lower  $K_2$ 's and thus this recommendation will produce conservative results.



TABLE 2. K-FACTORS ( $K_2$ ) FOR WATER AND WET CORAL BURSTS

Shot	Yield Mt	Water Depth ft	$K_2$ (Miller) <sup>6</sup>	$K_2$ (DASA)	$K_2$ (Average)
Bravo	15	0	610	2080*	785**
Zuni	3.5	0	1340	960	1150
Koon	0.11	0	530	725	630
Tewa	5.01	25.6	900	940	920
Flathead		136	710	670	690
Nectar		155	410	540	475
Yankee		160	760	940	850

\* Value exceeds  $(0.75)^2 \times 2900$ : not included in average.

\*\* Reflects Heffter's 960; see Table 1.



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## CHAPTER 4

### THE RADIOIODINE PROBLEM -- INHALATION

The discovery a decade later of severely damaged thyroids in those Marshallese who were exposed as children to the fallout from the March 1, 1954, BRAVO shot, in two instances amounting to complete ablation, and almost surely due to radioiodine,<sup>1, 2</sup> raised the question of the pathway by which that exposure occurred. In earlier analyses, it was generally assumed that ingestion through food and drinking water was the principal pathway, and not inhalation.<sup>3</sup> Direct data on the thyroid exposure were not available, partly because the problem was not appreciated then, and partly because gamma spectral analysis was in its infancy. Direct measurement of thyroid burden was not possible as it is today. On the other hand, it is readily demonstrable that there were massive external and internal exposures to a wide mix of fission products, including the radioiodines.<sup>4</sup>

The severity of the thyroid damage suffered by the Marshallese has raised the specter of a possible neglected but important danger from radioiodine in fallout particles. It also became important to investigate the possible routes of entry--ingestion or inhalation. This has led to recent studies by Cole<sup>5</sup> and Norman<sup>6</sup> on the threat of inhalation of radioiodine.

In the fission process, the iodine radionuclides (I-131, 132, 133 and 135) are mainly produced as decay products of the precursor nuclides of Sb and Te. Although these precursors are less volatile than iodine itself, almost all the iodine radionuclides would be expected to condense late in the temperature history of the nuclear cloud and thus on the surface of the fallout particles. This tendency for surface condensation would make the radioiodines liable to leaching and later assimilation by plants and animals. In addition, significant volatilization of iodine takes place in the evaporation of water solutions of iodide, and when moist warm air is passed over iodine-coated, pseudo-fallout particles. This effect can be orders of magnitude greater on coral (carbonate) than on siliceous particles.<sup>6</sup>

Cole found one set of circumstances in which he concluded that inhalation of radioiodine would be a real and significant hazard following nuclear attack: where people are in a fallout shelter near the most intense part of a fallout field,\* and there is appreciable standing water near the shelter ventilator intakes, and an extended thermal inversion. Fallout in rain he excluded because rain seldom occurs in coincidence with a strong inversion.

Examination of data from atmospheric tests does not yield a basis for clear-cut conclusions about the hazard of iodine inhalation. The

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\*Because iodine is usually fractionated out of the larger particles that fall in the intense part of the fallout field, these circumstances are generally limited to overlapping fallout fields.





## CHAPTER 5

### DETECTION OF FALLOUT BY THE PHYSICAL SENSES

The DCPA is concerned about advice to be given to people living in isolated or thinly populated areas who do not have the help of radiation measuring instruments to guide their actions in cases of possible fallout following nuclear attack. It is quite important that these people have as much time as possible to bring stock into barns and supply them with water and feed, to protect equipment from the elements, and to gather water and supplies for themselves and their families.

There is evidence that much if not all heavy fallout observed during atmospheric nuclear tests was visible as individual particles falling and striking objects, or as deposits accumulated on the surfaces of various objects.<sup>1,2</sup> Similar particulate fallout from volcanoes in similar quantities has been visible.<sup>3,4</sup>

For persons exposed to the particulate fallout from volcanoes, the forehead and nose are the most sensitive detectors of falling particles. At a stage of rapid accumulation of particles or under windy conditions, the presence of the airborne particles may be detected by irritation of the eyes or a gritty sensation on the lips and between the teeth. Usually at that stage of deposition the forehead will feel like sandpaper to the touch of the hand. The gritty sensation will also be felt on the hands and on bared arms. In rain, volcanic fallout has been observed on an automobile windshield behind the sweep of the wiper.

The DCPA might issue guidance to isolated individuals along these lines:

"If you are within one or two hundred miles of an explosion, you will know the country has been under attack by seeing flashes and, even if clouds intervene, by hearing shock waves, and you can confirm what has happened by listening to the radio. You will want to protect yourself and your family from fallout by going to the basement or to your storm celler, if you have one; however, fallout travels with the wind and will not arrive right away. Indeed, it may be several hours (or never) before fallout reaches you, and you probably will have time to protect your stock and equipment, and bring supplies into your own shelter. Probably you do not have a radiation-measuring instrument (if you do you can work outside until the instrument reads 0.5 R/hr), but heavy fallout can still be detected by one of these several clues:

1. Seeing fallout particles, fine, soil-colored, some fused, bouncing upon or hitting a solid object, particularly visible on shining surfaces such as the hood or top of a car or truck. A white board or piece of white paper on a flat surface may serve as a visual detecting device.



down fine particles as well as the large ones postulated in the example given. Even for the larger particles, detection under raining and cloudy conditions would be more difficult than under dry and clear conditions.

The Subcommittee reemphasizes that the implementation of such advice is a calculated risk, probably justified where instruments for detecting radiation are not available. Visible and tactile indices of fallout would provide valuable warning of danger, but any real control of radiation exposure must depend on instruments.



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## CHAPTER 6

### FEASIBILITY OF DEVELOPING FALLOUT-PREDICTION TECHNIQUES FOR OPERATIONAL APPLICATION

A number of fallout-prediction systems have been developed in response to a variety of needs.<sup>1</sup> These are widely used in damage assessment and training exercises, in scientific, engineering, and military studies, and in the prediction of fallout during the conduct of nuclear tests. The general aspects of such prediction systems is that they predict fallout patterns before the fact, using assumed or known yields, heights of burst, locations, and winds. None of them use reports of fallout intensity as a basis for fallout predictions at locations further downwind. Civil defense can use existing prediction systems only in planning and not operationally, since these systems require the inherently unknowable details of the enemy's plans for attack, and their accuracy is limited by uncertainties in weather parameters. What civil-defense authorities can hope to do operationally during and after the attack is to give the best possible advice to the population on where the fallout is, where it will go, when it will get there and at what levels, and where to move to--if that is a viable alternative. The kind of prediction system needed to do these things is quite different from existing systems.

In an effort to meet this need, a monitoring and prediction method based on observation of the unfolding fallout event was developed and tested by the Research Directorate of DCPA in the undocumented RESEX I exercise. The method utilized available weather data and techniques to predict the fallout sector once the location and general magnitude of detonation were established. Information on certain fallout parameters-- time when the exposure rate became 0.5 R/hr, time of peak exposure rate, time when exposure rate exceeded or decreased to 50 R/hr, etc.-- were reported by operating areas to higher headquarters (county, state, and regional EOC's) where the data were plotted and extrapolated in time and distance to provide warning and the same fallout parameters for locations farther downwind.

The existence of the RESEX 1 exercise shows that a real-time extrapolative prediction of fallout is to some extent feasible. However, there is a question whether such a system could be made to work in the attack situation, what with its critical dependence on the ability to receive data from the field and to disseminate information back. The questions have not been resolved to the Subcommittee's satisfaction. Nevertheless, it is self-evident that a system using current and real data is preferable to before-the-fact prediction.

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individual events where fallout patterns are simply superimposed. Events closer than this that are separated in time by more than 10 minutes may also be treated as independent bursts. For the exceptions, local fallout will be much increased.

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

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E H A Y E L N Y E L E I I P D E I

UNRESOLVED QUESTIONS ON FALLOUT  
OF INTEREST TO OCD

1. The portion of activity deposited in local fallout.
2. Effects on (1) of small changes in burst height.
3. Effects of soil type and building material on (1) above.
4. The radioiodine problem (inhalation).
5. Detection of fallout directly by the physical senses.
6. Feasibility of developing fallout prediction techniques for operational applications.
7. Radioactivity of craters of multi-megaton explosions.
8. Interaction of simultaneous surface bursts.

APPENDIX A

## PART II

### NOTES AND COMMENTS

#### ABOUT THE SUBCOMMITTEE MEMBERSHIP

The amount of research effort aimed at an improvement in understanding of the fallout radiation hazards that would be associated with nuclear war has steadily declined since the signing of the test ban treaty terminated the atmospheric weapons test program. Among the reasons why this has occurred are:

1. A general tightening of research budgets for defense purposes;
2. The difficulties and costs associated with doing meaningful research in the absence of an atmospheric weapons test program;
3. The practical limitations in the amount and reliability of reference fallout data from past atmospheric weapons tests.

As a consequence, the number of scientific and technical personnel active in this area of investigation also has declined markedly. In particular, the relatively small group of people with field-test experience continues to grow ever smaller.

The membership of this ACCD/NAS Fallout Subcommittee was carefully drawn so as to include a good sample of those people who have actual field-test experience and/or commensurate experience in other types of fallout research.

In the belief that many readers of this document would appreciate knowing something about the "credentials" of the individual Subcommittee members, the very brief summary of their backgrounds which appears below was prepared.

Melvin L. Merritt received his Ph.D. in physics from the California Institute of Technology in 1950. Since then he has been with the Sandia Laboratories, an AEC prime contractor in Albuquerque. He has participated in most of the U.S. nuclear test programs since, having had responsibilities for fallout and thermal predictions on atmospheric tests before 1962, and for ground shock predictions and effects on underground tests since. He was Effects Evaluation Scientist responsible for all safety activities on the Milrow and Cannikin tests on Amchitka.

His technical interests continue to relate to the safety of nuclear explosions and their effects on man, his structures, and his environment.

Eric T. Clarke received his Ph.D. in nuclear physics at MIT in 1944. In 1949 he participated in a program for long-range detection of nuclear explosions that succeeded in identifying the first Russian detonation through fallout analysis. From 1956 to 1967 he was in charge of, or closely associated with, various research studies performed by Technical Operations, Inc. for the predecessors of the Defense Nuclear Agency and the Defense Civil Preparedness Agency to determine the probable deposition and the radiation characteristics of fallout. He helped to organize a weapons effects group for, and in 1966 was the chairman of, the American Nuclear Society's Shielding Division.

Frank Cluff joined the Weather Bureau in 1946 as a Weather Observer. He continued in that employment for over 20 years, except for time out to obtain a B.S. degree in 1950 and an M.S. degree in 1956, both in meteorology at the University of Utah. In 1967 he joined the AEC, becoming Deputy Test Manager at the AEC's Nevada Test Site. He is now retired.

Robert E. Heft received his Ph.D. in physical chemistry at the University of Chicago in 1953. He has engaged in research concerning the physical and chemical properties of the particle populations generated by nuclear detonations. He was with the Air Force Technical Application Center until 1963 and since that time has been with the bio-environmental group at Lawrence Livermore Laboratory.

Carl F. Miller received his M.S. in physical chemistry from the University of California at Berkeley in 1948 and his Ph.D. from Iowa State University at Ames in 1951. He has been concerned with research on the formation, distribution, and deposition of fallout and the hazards due to the radiations therefrom as well as on various civil defense countermeasures to provide protection against these hazards. He participated in research projects covering several nuclear weapon field-test operations at the Nevada Test Site and at the Pacific Proving Grounds in the period of 1952 to 1962. These activities and research on civil defense subjects were performed while Dr. Miller was employed by the U.S. Naval Radiological Defense Laboratory, the Office of Civil Defense (as an Assistant Research Director), and the Stanford Research Institute; Dr. Miller is presently a staff member of The Dikewood Corporation.





CHAPTER 1 - THE PORTION OF ACTIVITY DEPOSITED  
IN LOCAL FALLOUT

1. In recent years there has been some concern that DCPA (and other) estimates of the fallout hazard that would be associated with a nuclear war may be excessively high. The basis for this concern was that the fallout models used in calculating this hazard were thought to seriously over-predict the amount of the radioactivity deposited in local fallout. According to the discussions of Chapter 1, this concern is not justified. Specifically, the K-factor value of 2000 (R/hr)/(kt/sq mile), which has been in general usage, varies from the figure of 1930 recommended in the report by the Subcommittee by a small percentage.

2. Past procedures for accounting for reduction in the ambient radiation levels attributable to ground roughness (unevenness in terrain features) have been either: (1) in effect reducing the amount of radioactivity (and consequently R/hr at any given time) assumed to be associated with a particular weapon's fallout pattern; or (2) assuming that personnel or other objects of interest, such as crops or livestock, receive some protection because of this ground roughness. Although the net result of either method of treatment is the same, logically the latter procedure is preferable since patently ground roughness would have little if any effect on the amount of activity deposited per unit area. By accepting the recommendations of Chapter 1, i.e., that a K-factor of 1930 be used in damage assessment models, then implicitly, procedure Number 2 for accounting for ground roughness effects is to be used.

This means, however, that when damage assessment of nuclear radiation effects from a hypothetical attack on personnel or things in the open is performed, an allowance for ground roughness protection must be made. Unless a specific evaluation of this ground roughness for the condition of interest is available, an average PF of 4/3 should be assumed.

3. The monitoring instruments of DCPA correctly read (assuming proper calibration of course) the ambient dose rates, and no instrument correction factor (as was necessary for older instrument designs) is required. (The test data on which the Subcommittee's recommendations were based largely came from these old instruments and have been adjusted, by using a multiplying factor of 4/3, to eliminate the instrument response factor.)



4. For the K-factor 1930 to apply, the detonation condition assumed is that of a true ground burst. That is, it is assumed that the incoming nuclear warhead does not detonate until it touches the ground.

E H K A I R E N I B H L A I N D E T I

CHAPTER 2 - EFFECTS OF SMALL CHANGES IN BURST  
HEIGHT ON THE AMOUNT OF LOCAL FALLOUT

1. When fallout models are used in hypothetical nuclear war studies, the weapons usually are assumed to detonate either as true air bursts, in which case no local fallout is assumed; or as true surface bursts, in which case about two-thirds of the total amount of radioactivity, as normalized to one hour after the detonation, is assumed to be deposited in local fallout. In an actual attack on a city some incoming enemy weapons are likely to impact on a building rather than directly on the ground, especially if they arrive along a non-vertical pathway such as one that would be followed by an incoming ICBM. If such weapons are fuzed to detonate on contact, the detonations therefore could occur some distance above the ground. Presumably for this reason, the amount of radioactivity in local fallout would be reduced compared to that of a true surface burst of the same type weapon. The material of Chapter 2 can be used to estimate how much the local fallout would be reduced due to this "height-of-burst" effect.

2. If Curve B of Figure 2 of the Fallout Subcommittee's report applies to the building height vs local fallout production phenomena as suggested in the report, an equation can be derived which, when corrected for ground roughness and instrument response, is as follows:

a.  $K_1 = e^{7.565 - 1.599 \times 10^{-2} \lambda}$  (R/hr)/(kt/sq mi) at 1 hour  
where:

- $\lambda = \text{scaled height of burst} = h/w^{1/3}$ 
  - h is height in feet of building where detonation occurs
  - w is in kilotons of total yield
- $\lambda$  is any positive value equal to or less than 100
- for  $\lambda$  values greater than 100, the  $K_1$  value for  $\lambda = 100$  applies.

b. To illustrate, assume that  $h = 400$  feet (i.e., about a 40-story building) and that the total yield, all of which is due to fission, is 1-MT. Then  $\lambda = 400/\sqrt[3]{1000} = 40$ . In which case

$$K_1 = e^{6.925} = 1017 \text{ (R/hr)/(kt/sq mi).}$$



This predicts that the local fallout from a 1-MT fission yield detonation on a 400-foot building would be about one half (1017/1930) the level that would be produced by the same weapon if detonated as a true ground burst.

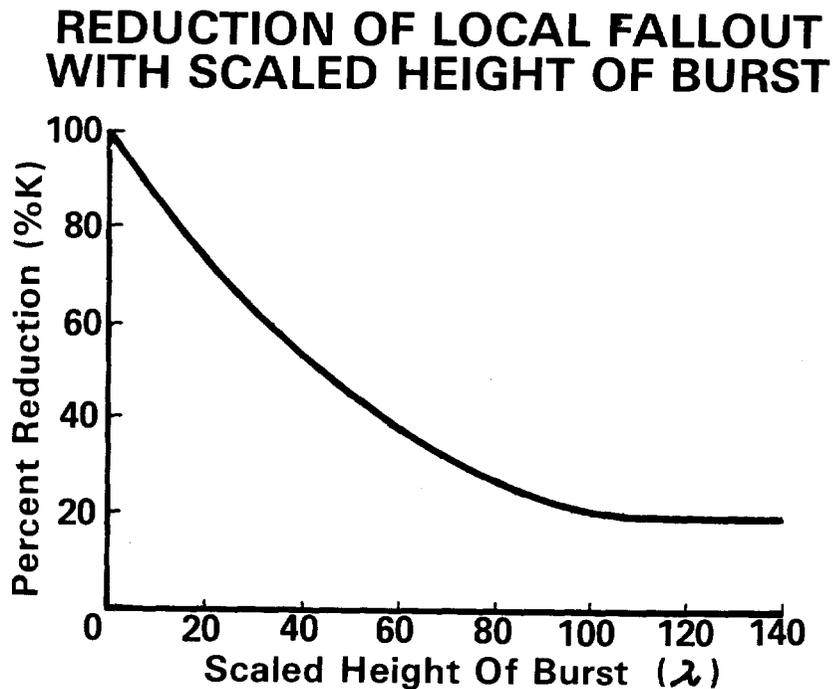
c. If only a part of the total yield comes from fission, then a factor to account for the fission fraction is needed; in which case the equation for K would become  $K = fK_1$ , where  $f$  = fission fraction.

d. Thus, the value of K to be used in a fallout model such as WSEG-10 is

$$K = f e^{7.565 - 1.599 \times 10^{-2} \lambda}$$

with the symbols defined as above.

e. A curve of percentage of local fallout for various values of  $\lambda$  compared to the fallout from a true ground burst is shown below.



CHAPTER 3 - EFFECTS OF SOIL TYPE AND BUILDING  
MATERIAL ON THE PORTION OF RADIO-  
ACTIVITY DEPOSITED IN LOCAL FALLOUT

With the cessation of U.S. atmospheric tests, and in particular, test detonations on or near the surface of the ground, there seems to be little promise of learning just how much difference various types of soil or other materials over which the detonation occurs would make with respect to the amount of radioactivity deposited in local fallout. The recognition, however, that current fallout prediction models probably somewhat overpredict radiation levels, is important. It provides one more reason why, in a nuclear war contingency, people should be urged to take the best available shelter and to improve whatever radiation protection they may have even though some standardized protection factor (say PF 40) cannot be achieved.



## CHAPTER 4 - THE RADIOIODINE PROBLEM--INHALATION

1. There is an insufficient basis for ruling out the threat of thyroid damage attributable to inhaled radioiodine vapor released in local fallout, even though it is the consensus of the ACCD/NAS Fallout Subcommittee and many others that the radioiodine inhalation threat is relatively minor compared to the ingestion threat.
2. However, there is little question that the danger of thyroid damage due to ingestion of radioiodine is significant and requires protective measures. The principal and probably only important ways by which radioiodine could be ingested are through drinking contaminated water or contaminated fresh milk. Thus, protection against ingestion could be achieved by avoiding water from open reservoirs, cisterns, and the like, where fallout has been deposited, and by keeping milk cattle from grazing on contaminated pasture or not using their milk if they do.
3. A third means of protecting the thyroid against ingested (and/or inhaled) radioiodine is through prophylaxis, i.e., using pre-administered stable compounds of iodine such as potassium iodide tablets to block the uptake by the thyroid of the radioactive iodine.
4. There could be radioiodine hazards to the U.S. population associated with a nuclear war even though the war did not directly involve the U.S., i.e., the so-called world-wide fallout that would result from an overseas nuclear exchange between, say, China and Russia. Also, there could be a radioiodine hazard due to an accidental release of radioactivity from a nuclear reactor accident.
5. It seems obvious that any national system designed to provide radioiodine protection should take into account the various possible threats, and it is equally obvious that the nature of the system may change depending on which threats are to be covered. Therefore, a final recommendation about the nature of the national protective system should await the conclusion of current studies of the problem.

CHAPTER 5 - DETECTION OF FALLOUT BY THE  
PHYSICAL SENSES

With the current limited availability of radiation detection instruments, especially in rural areas, wider publicity needs to be given to the statement in Chapter 5 of the report concerning the detection of radioactive fallout in dangerous quantities by an alert individual relying solely on his physical senses. It is important to note that this detection capability applies only to local fallout, and not to fallout from a Sino-Soviet exchange or from a nuclear reactor accident. (See the comments on Chapter 4.)



CHAPTER 6 - FEASIBILITY OF DEVELOPING FALLOUT-  
PREDICTION TECHNIQUES FOR OPERATIONAL  
APPLICATION

1. The Subcommittee states that "civil defense can use existing prediction systems only in planning and not operationally..."(underlining added).
2. It is important to understand that the prediction systems referred to in the report are for predicting what the dose rates (R/hr) or total doses will be at a particular time and at a particular place. "Prediction" as used here does not refer to estimating "time of arrival" of fallout (if it arrives) since such estimates would depend primarily on wind speeds which could be determined with considerable reliability.
3. Also, it is important to understand what is meant by "prediction techniques for operational application." Specifically, this term is used to describe the prediction after an enemy weapon actually has been detonated of fallout radiation dose rates at various times and at various locations. Thus, the Subcommittee's concern about use of existing prediction systems does not refer to civil defense operations such as pre-attack evacuation of cities, or calculations of risks based on studies of hypothetical attacks, or the like.
4. Even if an operational prediction scheme based on an extrapolation technique is developed, careful examination of the types of protective actions that might be taken based on the predictions is needed. This should include a careful analysis of the probable benefits in terms of the net expected lives saved or lost, and doses reduced or increased.
5. In any case, a policy which calls for the movement of people out of a predicted path of fallout, especially if they have been crowded into some NFSS-identified facility or other protected location, seems questionable. This is due to at least four factors: (1) inherent uncertainties of the predictions, as discussed above; (2) uncertainties about dependable communications; (3) the inherent difficulties of moving large numbers of people under unrehearsed and highly stressful conditions in a short period of time; and (4) moving them in a direction and for a distance not definitely known until the signal from the detection system has been received.

## CHAPTER 7 - RADIOACTIVITY OF CRATERS OF MULTI-MEGATON EXPLOSIONS

1. The information in this chapter is about the very high radiation levels to be expected in craters; it need have little practical impact on current civil defense planning. It has been recognized that emergency actions near the crater (such as rescue or firefighting) would be futile in any case because of the severity of the destruction that would have occurred so close in to ground zero. In other words, there would be no surviving people to be rescued or standing structures to be saved from fires.

2. It is noted that the craters, which might have been considered for burial grounds or repositories for debris and other material damaged beyond repair by the blast, because of the high levels of radioactivity should not be counted on for such use, at least in the early months following the detonation.

3. Although mostly academic, also it is noted that the intensely radioactive crater areas are not shown or accounted for in conventional fallout prediction models, nor do they show up in national depictions of the fallout conditions associated with hypothetical nuclear attack studies.

