DECLASSIFIED
Authority 44472

~~SECRET~~

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON 25, D.C.

MM

AW - Ecological Study

November 27, 1962

This looks good —
— what about 'Custom'?

Honorable Gerald W. Johnson
Assistant to the Secretary
of Defense (Atomic Energy)
The Pentagon
Washington 25, D. C.

Dear Dr. Johnson:

In reply to your letter of August 15, 1962, to Chairman Seaborg, I am enclosing a copy of a draft report entitled "The Biological and Environmental Consequences of Nuclear Attacks Using 'Clean' Weapons." This report was prepared by the Technical Analysis Branch, Division of Biology and Medicine. As noted in your letter to Dr. Seaborg, the report follows work done cooperatively between the Technical Analysis Branch and the Department of Defense Damage Assessment Center (DASA) lasting over the summer.

We would like to have your comments on the draft report. A final report will be issued after we hear from you. The DODDAC report was received in the Technical Analysis Branch on November 13, 1962. Much of the information in it had been received by mid-September informally, but most of the maps and some key graphs were not seen previously. We are now reviewing the DODDAC report and may make some changes in our own report as a result. Preliminary results of the DODDAC work were also sent to Chairman Seaborg under your transmittal letter of October 12, 1962.

We would also like to have your general comment as to the scope, emphasis, and degree of detail appropriate for studies such as this report represents so that we can plan more effectively for future work. The Technical Analysis Branch is just over half a year old and is still developing staffing and budgeting requirements. Working relationships between AEC and DOD on this general subject are yet to be developed beyond the exploratory point for this first study, and we would appreciate any comment you might now have on the general approach suggested by Deputy Secretary of Defense Gilpatric in his letter of March 6, 1962, to Chairman Seaborg.

The Technical Analysis Branch expects to rely heavily on resources primarily within the purview of the Department of Defense and --

When separated from enclosures, handle this document
as UNCLASSIFIED
(Insert proper classification)

DOCUMENT TRANSMITTED
HEREWITH CONTAINS
~~SECRETRESTRICTED DATA~~

DEC 3 '62

as an example -- has already made arrangements for work to be carried out at the U. S. Naval Radiological Defense Laboratory and at the RAND Corporation.

Sincerely yours,

R E Hollingsworth

Acting General Manager

Enclosure:
  Report cy 1A

DECLASSIFIED
Authority 44472

~~SECRET~~

This document consists of 44 pages
No. 1A of 5 Copies, Series A

DRAFT

THE BIOLOGICAL AND ENVIRONMENTAL CONSEQUENCES OF NUCLEAR ATTACKS USING "CLEAN" WEAPONS

November 14, 1962

U. S. ATOMIC ENERGY COMMISSION
Division of Biology and Medicine
Technical Analysis Branch

~~RESTRICTED DATA~~

This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

DEC 3 '62

on Appd 11/27/62

~~SECRET~~

DECLASSIFIED
Authority 44472

~~SECRET~~

TABLE OF CONTENTS

~~SECRET~~

DECLASSIFIED
Authority 44472

~~SECRET~~

DRAFT
TAB:DBM
HH:det
10/8/62

~~Unclassified Title: Special Nuclear Attack Study Problem~~

Un~~C~~lassified Title: The Biological and Environmental Consequences of Nuclear Attacks Using "Clean" Weapons

Reference: Letter from Gerald W. Johnson, Assistant to the Secretary of Defense (Atomic Energy) to Chairman Seaborg, August 15, 1962

Introduction

The Department of Defense, by the letter referenced above, confirmed its previously informal request to the Atomic Energy Commission that it undertake a special nuclear attack study. The problem was to make an assessment of the immediate and the longer term post-attack biological and ecological effects of a nuclear attack, comparing different targeting, weights of attack and degrees of weapon "cleanliness" expressed as the percentage of total bomb energy yield coming from fission.

For this problem, the general target was to be U.S.S.R. The weapons studied would thus be U.S. designs.

The problem was first presented to the Technical Analysis Branch, Division of Biology and Medicine by Dr. Johnson at a meeting in his office. At the same time, arrangements were made whereby the Department of Defense Damage Assessment Center (DODDAC, part of DASA) would carry out a preliminary analysis including the following steps:

1. Postulate attack patterns, including choice of targets and numbers and sizes of weapons
2. Provide other, mostly technical, input information concerning the country to be attacked, such as population distr[illegible] conditions, type of agriculture, maps, etc.

~~RESTRICTED DATA~~
This document contains restricted data as defined in the Atomic Energy Act of 1954. Its transmittal or the disclosure of its contents in any manner to an unauthorized person is prohibited.

~~SECRET~~

3

3. Employ existing calculation methods, where available, to estimate selected prompt effects such as blast casualties and fatalities.
4. Develop new calculation methods, where needed, to cover gaps which appeared too important to neglect. The main example of this was the cooperative effort with Dr. Carl Miller, Assistant Director for Postattack Research OCD, to develop a method for taking into account in predicting fallout such factors as:
    a. Fractionation of fission products
    b. Particle size and solubility of fallout particles as they relate to potential availability for incorporation of the associated radionuclides into the biosphere and, potentially, into animals and persons.
5. Carry out, by digital computer, the actual calculations of selected prompt effects and related information upon which the AEC's assessment of biological and ecological effects would be based.
6. Present the results of this work in suitable report form, including tables, graphs and maps.

Input information on weapon design characteristics was supplied by Los Alamos to AEC to DODDAC. Information from Livermore ~~is understood to have been~~ was furnished to DODDAC through Dr. Johnson's office.

Input information on the physical and chemical characteristics of U.S.S.R. soils was provided by the World Soil Map Group, U.S.D.A., and the Military Geology Branch.

Dr. Carl Miller of OCD ~~, as an individual,~~ worked with DODDAC on calculation methods, as noted above.

4

Scope of This Report

Work done by DASA-DODDAC is being reported in detail by themselves.[1] This report will include an appropriate discussion of the input information and technical assistance provided by others.

The AEC report - this report - will, therefore, consider the DODDAC report as suitable for direct citation and reference. Its material will not be duplicated here, except as an essential part of a developing argument or conclusion.

Scope of the Special Attack Study Problem: Cases Selected

A study of the biological and ecological effects of attacks using "clean" weapons almost demands an approach that is, at least in part, comparative with similar attacks using "standard" (thermonuclear) weapons. Direct fatalities, for example, are easily and effectively studied by this approach. Other effects, such as those resulting from contamination of the ground, would seem to need some degree of absolute evaluation as well, so as to give a feeling for relative importance.

A major difficulty in comparative studies, however, is that the comparisons may be made under such limited circumstances as to limit in turn the value of the comparisons because they can't be generalized.

For this study time limits were severe and, therefore, a minimal number of cases (each "case" being a defined attack situation) were chosen. These were based on the following:

Type of target:

1. Military targets only (U.S.S.R.)
2. Military targets as above and industrial targets combined

---

[1] Title of DODDAC report:________________referenced simply as "DODDAC REPORT" throughout.

Attack weights (total yield):

1. 586 MT on military targets, or 971 MT on combined targets
2. 1869 MT on military targets, or 3014 MT on combined
3. 6037 MT on military targets or 10,000 MT on combined

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

Type of burst:

1. All air burst
2. All surface burst

All of the cases chosen were "pure cases", i.e., no mixtures of weapon designs nor of surface and air bursts.

Weapons were used in 1, 5, and 20 MT sizes but, of course, the "spectrum" is not identical for the various cases.

The air burst attacks were considered to lead to no radiation effect. The number of these cases (6) is therefore independent of weapon design. For the one standard and two clean designs used for surface burst attacks, 18 additional cases result. A total of 24 cases thus forms the structure for this study.[1/] These cases are tabulated in Table I.

Prompt Damage Assessment: Input Information and Methods for Estimation

All of this is covered in the DODDAC REPORT as to approach and results. Some comment on the methods and results are interspersed in later sections of this report. The relatively low classification of this study problem makes it ideal for continuing future study leading toward improved quality of input data and methods of estimation.

[1/] Note: An additional 30 cases were worked through by DODDAC for other weapon designs, but these do not form a part of the AEC study. See DODDAC REPORT, page 12.

DECLASSIFIED
Authority 44472

~~SECRET~~

The Prompt Effects of the 24 Attack Situations

Here we consider the DODDAC estimates of the following effects:

1. numbers of surviving people
2. numbers of persons defined as "well"
3. numbers of persons defined as "well" but who also received 300 r or more of external gamma radiation from local fallout
4. the average cumulative external gamma dose to the surviving persons from local fallout
5. ~~the average equivalent residual dose (ERD) to the surviving persons from local fallout~~
6. numbers of surviving livestock
7. levels of land contamination from local fallout.

~~SECRET~~

7

TABLE I

Special Attack Study Problem: Cases Selected

AIR BURST

Military targets	
586 MT	*
6037 MT	*
Military targets (as above) combined with industrial targets	
971 MT	*
3014 MT	*
10,000 MT	**
(Total)	6

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

[redacted]

Note: each attack weight was programmed for a spectrum of weapon sizes, selected from three: 1 MT, 5 MT, and 20 MT total yield per weapon

All but the last of these are summarized together in Table II.

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

[redacted]

This is to be expected.

From Table II, one can draw the following observations:

1. The number of animals surviving stays in rough proportion to the number of persons surviving. This is not surprising in view of the fact that the attack patterns[1], even for military attacks, tend to coincide--in a country as large as the U.S.S.R.--with the places where people live and where agriculture is carried on. This is not to say, however, that the surviving animals and people are necessarily located sufficiently close to each other to permit an easy resumption of the animal industries post-attack.
2. When clean weapons are used for surface bursts, only in the largest attack sizes does the number of survivors (people and livestock) tend to drop well below those for air bursts.
3. The average cumulative external gamma dose to the survivors for the clean weapon attacks is about 1/3, in each case, that for the standard weapon attacks for surface bursts. The worst case for clean weapons (196 r for 10,000 MT combined targets) is not nearly as bad as three of the six standard weapon cases (391 r, 410 r, 622 r for 3014 MT combined, 6037 military, and 10,000 MT combined, respectively).
4. The columns giving the percentage of well people receiving over 300 r cumulative external gamma dose must be interpreted carefully.

---

[1] DODDAC REPORT, page 241

These percentages are of pre-attack populations, as noted in the table. Thus, if survival itself is low, obviously that portion who are "well and highly exposed" will also tend to be low.

DECLASSIFIED
Authority 44472

TABLE II

Summary of Prompt Effects for the 24 Nuclear Attack Situations1/, 2/

	AIR BURST					[redacted]									
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Combined targets															
971 MT	.8	.75	0	0	-	.63	.53	.09	224	.75	.81	.73	0	80	~~.98~~ .96
3014 MT	.76	.73	0	0	-	.46	.35	.09	391	.48	.69	.59	0	114	.83, .82
10,000 MT	.70	.68	0	0	-	.18	.13	.02	622	.20	.43	.29	.02	196	.46
Military targets															
586 MT	.96	.94	0	0	-	.84	.76	.06	132	.86	.96	.91	0	38	.98
1869 MT	.94	.93	0	0	-	.73	.62	.09	215	.68	.90	.82	0	64	.91
6037 MT	.91	.88	0	0	-	.49	.39	.10	410	.39	.74	.62	.01	118	.68

LEGEND

(1) Surviving persons, fraction of pre-attack population (3/)
(2) Well persons, fraction of pre-attack population (4/)
(3) Well persons, as above, who also received 300 r or more lifetime dose (5/)
(4) Average lifetime dose to survivors (5/)
(5) Surviving cattle, fraction of pre-attack population (6/) (7/)
(1) As above
(2) "
(3) "
(4) "
(5) "
(1) "
(2) "
(3) "
(4) "
(5) "

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

NOTE: See following page for footnotes.

11

Footnotes for Table II (preceding page)

1/ From DODDAC REPORT, which gives background for development of these numbers.

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

[redacted]

3/ Pre-attack population: 210 million persons

4/ See DODDAC REPORT for interpretation of "well"

5/ External gamma dose from local fallout, cumulated

6/ Pre-attack population: 71 million cattle (see DODDAC REPORT for sheep and pigs)

7/ The DODDAC damage assessment system does not estimate cattle fatalities from air bursts. For most of the surface burst cases, percentage-wise the cattle do slightly better than the people, and this would not be unreasonable to assume for the air burst cases too. Therefore, use the percentages in column (1) as a rough guide. If anything, the percentage survival of cattle would be even higher, approaching 100% survival; the survival of the rural human population for the air burst attacks is estimated at 100% (DODDAC REPORT, p. 14).

Estimates of levels of land contamination are presented in the DODDAC REPORT for all the surface burst cases, for two situations:

1. Atoms per square foot deposited on cultivated land (cropland) in the U.S.S.R. for mixed fission products, for 6 selected fission product radionuclides, (biologically available) for 2 selected soil-induced radionuclides, and for residual weapon material radionuclides.
2. Atoms per square foot retained on the foliage of all U.S.S.R. agricultural land (cropland plus grazing land), as above.

This information is presented graphically in the DODDAC REPORT as a series of cumulative distributions showing fractions of land area not contaminated above a specified number of atoms per square foot. Not all of the different types of contamination, as listed above, are actually shown on the graphs because of the crowding that would be caused, but multipliers are given by which any curve not shown can be readily derived.

Information taken from the DODDAC REPORT is summarized in Tables III and IV. The plan of presentation has been to take a look at the levels of contamination corresponding to the contours containing the most contaminated 10% - and the most contaminated 25% - of the U.S.S.R. land area. Such contours are, of course, fictitious in the sense that the actual areas of highest land contamination are spotted about over the U.S.S.R. The DODDAC REPORT maps suggest the actual, geographical distribution.

The H+1 dose rate from all radioactive atoms - at the 10% and 25% contours - (taken from Table III and columns 5A and 6A, Table IV) are plotted for the different attacks in Figures 1 and 2. These plots show that the H+1 dose rates are lower by about a factor of 10 for the clean weapons.

The result can be viewed in another way when combined with the livestock survival information. Table V shows the survival of livestock (only cattle are shown, but - as the DODDAC REPORT graphs show, the result is little different for pigs or sheep/goats) outside (i.e., on land contaminated less) the 10% - and the 25% - contours for standard and clean attacks. For the clean attacks, some cattle survive inside the 25% contour and, except for the two largest attacks, even the 10% contour. For the standard-weapon attacks, only the smallest attack gives any appreciable survival of cattle inside the 25% contour, and in no case is there any survival inside the 10% contour. This result is to be expected from Figures 1 and 2.

It might be asked why the 10% and 25% contamination contours were chosen, and why not the 50% or even the 75% contours (i.e., why not look at less contaminated land). The reason is apparent from inspection of the DODDAC REPORT land contamination graphs, giving cumulative distributions of land contamination, atoms/sq. ft. These might be regarded as the result of summing up areas inside the actual H+1 fallout contours as estimated for the U.S.S.R. land area. The horizontal axis of the graphs ranges from roughly 10^{16} atoms per square foot of mixed fission products down to 10^{12} or so before going off scale. The lower value represents an H+1 dose rate of about 1 r/hr. One visualizes that lower contours will not include much more land area. But not all of the total U.S.S.R. land area is accounted for; much of it is uncontaminated from local fallout (as predicted by the DODDAC model). Therefore, the 10% of the U.S.S.R. agricultural land area most contaminated is really a higher

TABLE III

Summary of Land Contamination Estimates for Two Agricultural Situations[1]

[redacted]

	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
Combined targets								
971 MT	2.0×10^{15}	7.3×10^{14}	1000	370	8.0×10^{13}	3.0×10^{13}	40	16
3014 MT	6.5×10^{15}	2.7×10^{15}	3250	1350	2.6×10^{14}	1.08×10^{14}	130	54
10,000 MT	2.2×10^{16}	1.2×10^{16}	11100	6000	8.8×10^{14}	4.8×10^{14}	440	240
Military targets								
586 MT	1.3×10^{15}	2.8×10^{14}	650	140	5.2×10^{13}	1.1×10^{13}	26	6
1869 MT	4.3×10^{15}	1.3×10^{15}	2150	650	1.7×10^{14}	5.2×10^{13}	85	26
6037 MT	1.5×10^{16}	5.8×10^{15}	7500	2900	6.0×10^{14}	2.3×10^{14}	300	115

LEGEND

(1) Fission product contamination at contour enclosing highest 10% of cultivated land area, atoms/sq. ft.

(2) Fission product contamination at contour enclosing highest 25% of cultivated land area, atoms/sq.ft.

(3) Dose rate at H+1, r/hr (2/) at 10% contour from mixed fission products only

(4) Dose rate at H+1, r/hr (2/) at 25% contour from mixed fission products only

(1) As above

(2) "

(3) "

(4) "

---

[1] From DODDAC REPORT, which gives background for development of these numbers, except as noted below

[2] Calculated from 10^{12} fissions/sq.ft. = 1 r/hr at H+1.

~~SECRET~~

TABLE III-B

Summary of Land Contamination Estimates for Two Agricultural Situations[1]

(Surface Burst Cases Only)

[redacted]

Combined targets				
971 MT	1.3x10^14	--	5.0x10^12	--
3014	7.8x10^14	2.1x10^14	3.1x10^13	8.4x10^12
10,000 MT	2.2x10^15	9.8x10^14	8.8 x10^13	4.0x10^13
Military targets				
586 MT	2.0x10^13	--	8.0x10^11	--
1869 MT	3.5x10^14	4.5x10^13	1.4x10^13	1.8x10^12
6037 MT	1.0x10^15	4.0x10^14	4.0x10^13	1.6x10^13
LEGEND	Fission product contamination at contour enclosing highest 10% of total agricultural land area, atoms/sq. ft.	Fission product contamination at contour enclosing highest 25% of total agricultural land area, atoms/sq. ft.	As above	"
	(5)	(6)	(5)	(6)

NOTE: See preceding page for footnotes.

~~SECRET~~

DECLASSIFIED
Authority 44472

~~SECRET~~

TABLE IV

Relationship between fission products and other radionuclides as contributors to the H+1 dose rate over agricultural land

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

[redacted]

Combined targets				
971 MT	40	80	16	32
3014 MT	130	260	54	108
10,000	440	880	240	480
Military targets				
586 MT	26	52	6	12
1869 MT	85	170	26	52
6037 MT	300	600	115	230

LEGEND

Dose rate at H+1, r/hr at 10% contour, from fission products only (from Table III)	Dose rate at H+1, r/hr at 10% contour, from all radionuclides	Dose rate at H+1, r/hr at 25% contour, from fission products only (from Table III)	Dose rate at H+1, r/hr at 25% contour, from all radionuclides
(3)	(3A)	(4)	(4A)

(Table III column number)

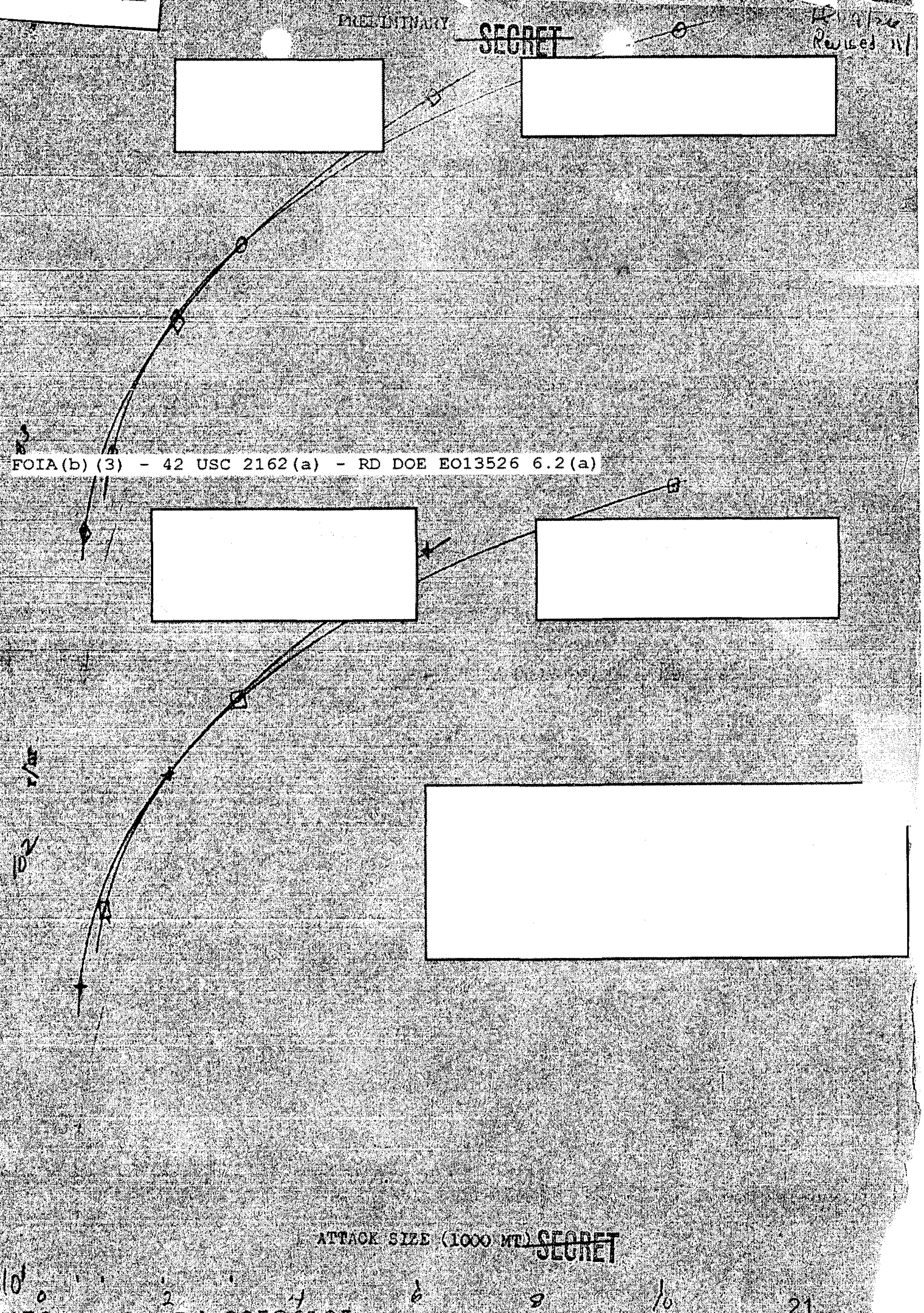
~~SECRET~~

17

DECLASSIFIED
Authority 44472

PRELIMINARY ~~SECRET~~

[illegible]
Revised 11/



[redacted]

[redacted]

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

[redacted]

[redacted]

[redacted]

ATTACK SIZE (1000 MT)

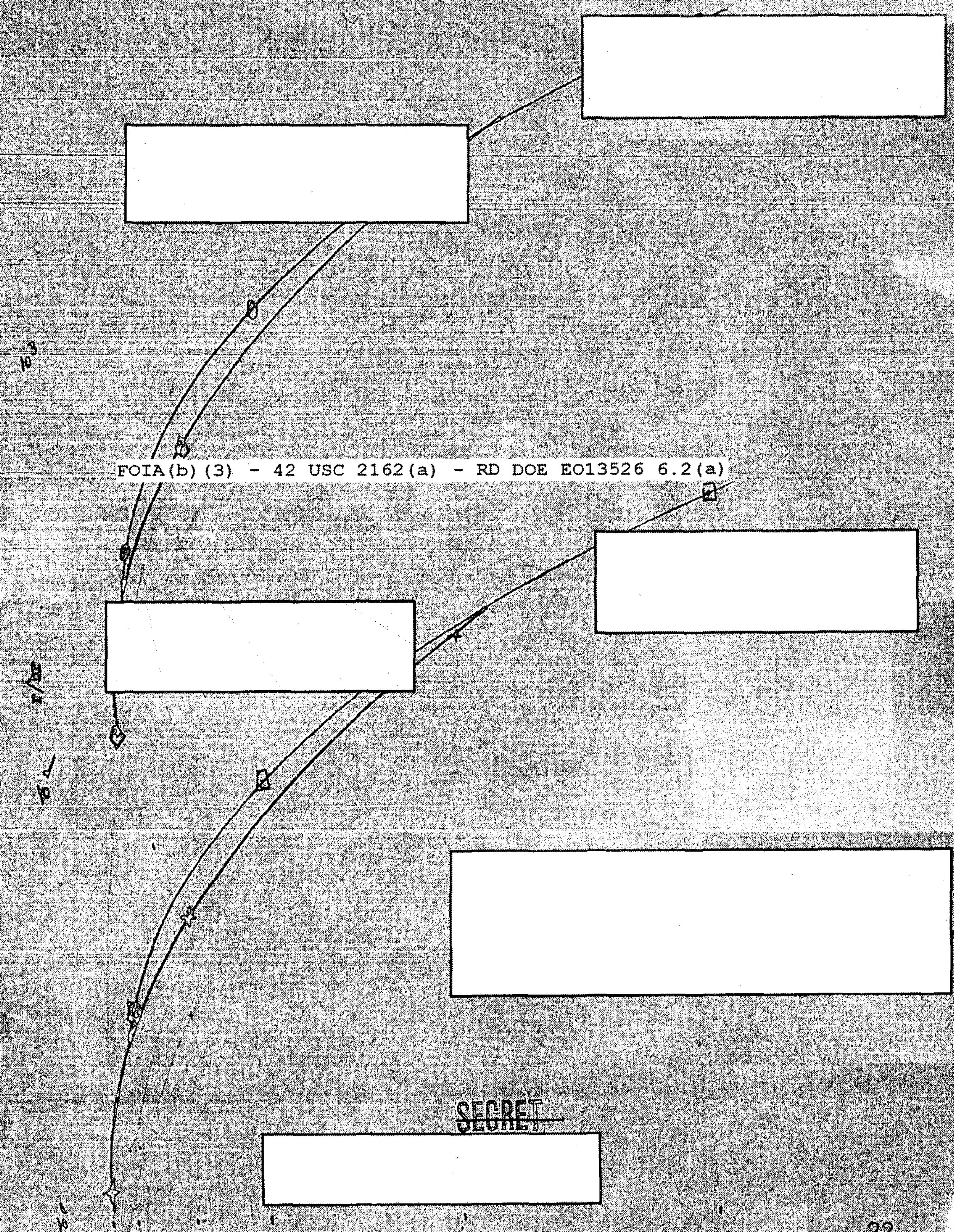
~~SECRET~~

DECLASSIFIED
Authority 44472

PRELIMINARY

~~SECRET~~

9/22
Revised 11/14/62



FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

~~SECRET~~

[redacted]

TABLE V

Livestock Survival[1]

[redacted]

	(5)[3]	(7)	(8)	(9)	(10)	(5)[3]	(7)	(8)	(9)	(10)
Combined targets										
971 MT	.75	.75	.69	1	.92	.96	.88	~~.57~~ .73	.91	.76
3014 MT	.48	.48	.48	1	1	.82	.80	.68	.97	.83
10,000 MT	.20	.20	.20	1	1	.46	.46	.44	1	.96
Military targets										
586 MT	.86	.84	.69	.98	0.80	.98	.92	.68	.94	.69
1869 MT	.68	.68	.65	1	0.96	.91	.87	.75	.96	.82
6037 MT	.39	.39	.39	1	1	.68	.68	.63	1	.93

LEGEND

(5)[3]	Fraction of pre-attack population surviving	(5)[3]	As above
(7)	Fraction of pre-attack population surviving outside 10% contour ([2])	(7)	"
(8)	Fraction of pre-attack population surviving outside 25% contour ([2])	(8)	"
(9)	Fraction of survivors surviving outside 10% contour ([2])	(9)	"
(10)	Fraction of survivors surviving outside 25% contour ([2])	(10)	"

---

[1] This table is for cattle only; the DODDAC REPORT gives similar information
[2] Contours of highest land contamination as used in Table III.
[3] From Table II

20

percentage of that agricultural land area having any contamination at all. There is little point in estimating contamination levels lower than that shown in the DODDAC REPORT.

Appendix F of the DODDAC REPORT gives information on the decay rate of mixed fission products, soil-induced radionuclides, and weapon material residual induced radionuclides. Figure F-17ff. (p. 68ff.) gives the time integrals of the dose rate curves for two assumptions about fallout arrival time (one hour, and five hours). This information is developed for a single weapon and does not take into account the effect of overlapping fallout patterns from multi-weapon attacks. The information is a fairly good indicator, however, of the origin of the external gamma dose over various periods of time.

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

1/ This paragraph added at the last minute after DODDAC REPORT was received; it will probably be slightly revised and relocated in the final report.

Exposure Dose from Internal Emitters

DODDAC made no estimates of the exposure dose to persons or animals (or plants) from internal emitters. This ~~subject is very complex,~~ requir~~ing~~es treatment for each chemical element - in some cases more than one nuclide - or at least groups of elements. It is common practice, however, to "eliminate" many of the fission product and neutron-produced radionuclides from consideration by qualitative arguments. These may be summarized as follows:

1. The half-life is extremely short, making it fairly clear that little or none of the radionuclide would reach the bioshpere.
2. The half-life is extremely long, leading to the argument that the radionuclide is essentially stable, or in any event there is time later to "do something" about it. This argument would have to be used carefully with, say an alpha-emitting bone-seeker.
3. The element to which the radionuclide belongs is known to be transferred into the biosphere - or at least into the parts of the biosphere where it could be incorporated into man - very poorly. That is, it is not taken up by plants, or by animals, or if ingested by man even, is

readily eliminated from the body.

4. The radionuclide in question has a sister whose probable dose contribution is so much larger as to make consideration of both an unnecessary burden when time is limited.

Needless to say, no special review of internal emitter toxicology and supporting information relating to transfer through the biosphere has been made for this report. Both DODDAC and we have made arbitrary choices of which radionuclides to even attempt to make a quantitative estimate of dose for. It is clear, however, that the validity of this approach for the purposes of this report should be assessed keeping the following factors in mind:

1. 16% and 82% of the U.S.S.R. population are estimated dead from the smallest and the largest standard-weapon attacks respectively. 4% and 57% are dead from the corresponding clean-weapon attacks.
2. The survivors of the smallest and largest standard-weapon attacks received an estimated lifetime external gamma dose of 130 r and 620 r respectively. From the clean attacks, 40 r and 200 r respectively.
3. Some internal emitters, notably I-131, are by present methods estimated to produce rad doses to the thyroid ranging in the thousands and hundreds of thousands if no countermeasures whatever are taken. This is true for both standard-weapon and clean-weapon attacks, but the fission product doses in this report would be estimated to be, for the clean attacks, 4% of the estimated doses for the standard-weapon attacks, however estimated.

4. Even in the absence of countermeasures, obvious factors such as the lack of live milk cows to transfer I-131 to milk, in the heavily devastated regions, ought to be taken into account.

In short, it appears possible that omitting certain radionuclides from quantitative consideration is not introducing errors appreciably larger, but perhaps much smaller, than those errors already included in the overall assessment of these nuclear attacks.

The following radionuclides are given some specific attention in this report; these are picked out from those whose amounts are estimated in the

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a) [redacted]

There are two general pathways for these radionuclides to reach the diet:

1. Uptake by plants following deposition on soil, with a possible following step of uptake by animals grazing the plants or eating hay.
2. Retention by the surfaces of plant foliage, with a possible following step of uptake by animals grazing the plants or eating hay.

Table VI has been worked out from a brief review of the literature[1] on plant uptake from soil. Some radionuclides listed are eliminated for further consideration because of half-life. Others are eliminated because of low uptake by plants.

Of the radionuclides listed in Table VI, only Sr-89 and Sr-90 would be at all likely to constitute an ~~additional~~ exposure hazard worth considering in addition to the external gamma radiation dose insofar as uptake from soil is concerned. For these radionuclides, the maximum exposure dose to persons from clean-weapon attacks would be estimated as about 4% of that for the corresponding standard-weapon attacks.

~~Now~~ With respect to foliar contamination, the DODDAC REPORT says that foliar retention of radionuclides is estimated as a function of fallout particle size according to the following scheme:

---

[1] See acknowledgments

TABLE VI

Fractional Uptake by Crops Per Year from Soil

**Sr-89	0.01
Sr-90	0.01
Cs-137	0.001
*Ba-140	0.001
*I-131	0.01
[redacted]	
Pu-239	10^{-7}
Ru-106	0.001
[redacted]	
*U-237	?

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

*/ Short life precludes uptake hazard

**/ Possible uptake hazard for only one year

[redacted]

DECLASSIFIED
Authority 44472

~~SECRET~~

Atoms/ft^2 foliar retention/ Atoms/ft^2 total	Particle size (ξ)
100%	$0 < \xi \leq 50\,\mu$
0%	$\xi > 50\,\mu$

Foliar deposition is, furthermore, unlikely to be of much importance beyond the first growing season after the heavy fallout. This is based on the assumption that the great bulk of the world-wide fallout would occur within one year following the attack, and the local fallout much sooner.

Of the six fission products, certainly Sr-89 could contribute a bone dose of the same order of magnitude as that from Sr-90. The Sr-89 dose would mostly come from the foliar deposition, whereas the Sr-90 dose comes not only from foliar deposition but from soil uptake.

I-131, furthermore, can produce doses in the thousands of rads or more to the human thyroid principally from foliar deposition.

But, again, maximum doses from clean-weapon attacks would be estimated to be about 4% of the maximum doses from standard-weapon attacks.

Both Sr-89 and I-131 have half-lives in the 5 to 50 day range, which tends to maximize the foliar deposition route of entry. Longer half-lives permit uptake over longer periods than one growing season; shorter half-lives scarcely permit any uptake at all.

[redacted] Foliar deposition is probably the route of entry, if any, because uptake from soil (Table VI) is low. Plutonium is not metabolised by animals to an appreciable extent. Intake from eating vegetables with surface contamination is possible. [redacted]

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

~~SECRET~~

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

	$MPC_{soluble}$1/	$MPC_{insoluble}$2/
[redacted]		
Sr-90	10^{-6}	$4x10^{-4}$
Sr-89	10^{-4}.	$3x10^{-4}$

1/ relates to critical organ dose
2/ relates to gut dose

[redacted]

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

~~In Appendix A~~ Below we give an estimate of the maximum doses from 4 internal emitter fission products to be expected from the various attacks on the assumption of no countermeasures. For I-131 we do not believe this assumption is valid. These estimates take into account both foliar and soil uptake, as appropriate, but are nevertheless only rough estimates.

Carbon-14 is usually treated separately, its mode of entry to man being virtually unique because of the role of carbon chemistry in organic matter. The production of C-14 is estimated by DODDAC to be approximately 50% higher for the clean weapon attacks than for the standard weapon attacks. This will be true for air burst attacks as well as surface burst attacks. The air burst attacks are estimated to produce twice as much C-14 as the surface burst attacks, because of the difference in geometry (in surface burst attacks, 50% of the escaping neutrons are assumed to be absorbed in soil). The genetically effective dose from this source for the levels of attack of this report is in the range of from a fraction of a rem to 2 or 3 rem.[1] [redacted]

---

[1] Computed for a fast equilibration time of 27 years and a slow one of 200 years. These doses are not the 8000-year "infinity" doses.

An estimate of the size of the internal emitter dose has been made, using as a basis for estimation the contamination levels of all agricultural land (cultivated plus grazing) at the 10% and 25% contours as previously defined. Devastation, including the death of milk cows, would be expected to reduce the contribution to dose from the more heavily contaminated areas. This effect has not been allowed for.

The estimate is summarized in Table VII. Clearly the important contributor is I-131, although some of the others contribute sizable doses in relation to the prompt external gamma dose.

It should be carefully noted that the internal emitter rad doses in Table VII are <u>not</u> average values for the survivors but are upper limits of what might be expected from food-chain uptake at the contours representing the most highly contaminated land in the U.S.S.R. (total agricultural land, 10% and 25% contours as noted above). Even for Table VII, some of the levels are so low as not to show on the DODDAC REPORT graphs (small attacks, 25% contour).

The doses in Table VII assume <u>no</u> countermeasures and are total lifetime doses. For I-131 and Sr-89, dose delivery is in weeks and months. [redacted]

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

TABLE VII

Estimate of Upper Limit of Radiation Exposure from Internal Emitters[1]

Attack	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
971	59,000	(low)	Sr-89: < 0.5 to 50 rads	2,300	(low)	Sr-89: <0.02 to 2 rads
3,014	350,000	95,000	Sr-90: <1.3 to 130 rads	14,000	3,800	Sr-90: < 0.05 to 5 rads
10,000	990,000	440,000	Cs-137: <0.3 to 30 rads	40,000	18,000	Cs-137: <0.01 to 1 rad
586	9,000	(low)		400	(low)	
1,869	160,000	20,000		6,300	800	
6,037	450,000	180,000		18,000	7,200	
LEGEND	(11) Maximum dose to thyroid expected from I-131 at 10% contour[2] (total agricultural land), rad	(12) As above, 25% contour, rad	(13) Range of dose expected from internal emitters, 10% contour[3]	(11) As above	(12) As above	(13) As above[3]

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

Note: See following page for footnotes.

Footnotes for Table VII (preceding page)

1/ Not shown on Table:

Pu-239 - not higher than Sr-90, standard or clean weapon attacks

[redacted]

C-14 - 2-3 rem maximum. Air burst attacks twice as high as surface burst; clean weapon attacks 1½ times as high as standard weapon attacks.

2/ i.e., 10% most highly contaminated

3/ (See Table)

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

The Effects of Ionizing Radiation on Terrestrial Ecosystems[1]

Research on environmental biology pertaining to the effects of ionizing radiation tends to fall into two categories:

1. Studies of the transport and distribution of radionuclides in plants and animals and chains of them, especially the food chain leading to man.
2. Studies of the effects of ionizing radiation on ecological systems themselves.

Relatively much emphasis has been put on the former, especially for a few radionuclides such as Sr-90, but relatively little on the latter. It is only recently discovered that certain plants are damaged by total radiation exposures in the same range as those which cause damage in mammals.

Certain plants are especially sensitive to damage from ionizing radiation. The gymnosperms include some of the most radiosensitive of plants; the algae and bacteria; some of the most resistant. The range of sensitivity is of the order of several thousand-fold. For example, chronic exposure of pitch pine (Pinus rigida Mill.) trees to average levels of less than 5 r/day for several years has killed more than 90% of these trees, while exposures in the range of 1-3 r/day inhibit diameter and needle growth. Near the other extreme of sensitivity among the higher plants, Arabidopsis survives chronic exposures of several thousand r/day. Bacteria, algae and fungi are in many instances still more resistant. In general the trend of research on both somatic and genetic effects on higher plants is toward recognition of effects at lower and lower exposures.

---

[1] This part draws heavily, with much direct citation, on the following reference: Woodwell, G. M., The Effects of Ionizing Radiation on Terrestrial Ecosystems, report BNL 6408.

Differences in sensitivity to damage are not restricted to differences between species but also occur at various times during the life cycle of an organism. Reproductive stages in plants are apparently generally more sensitive than vegetative stages, lethal effects occurring during flowering and seed set at approximately 1/4 the exposure rate necessary to cause 100% mortality among mature plants. Tables VIII and IX illustrate this differential radiosensitivity. In animals, variations in sensitivity among different stages especially in insects, have been recognized for many years. The implication is clearly that time-of-year for an attack will have a bearing on ecological response.

The effects of exposure of plants range from death through varying degrees of growth inhibition to effects on reproductive capacity.

It is important to recognize that in general the research which has described these effects in plants and which has yielded estimates of sensitivities has been done on small populations under cultivated conditions in greenhouses or gamma radiation fields, conditions specifically designed to reduce variability attributable to environmental stress. The introduction of the various forms of environmental stress characteristic of natural ecological systems can be expected to intensify the damage from exposure to ionizing radiation and to produce effects measurable at lower exposure levels possibly to produce additional effects not recognized previously.

For simplicity, we have divided possible effects on ecosystems into short-term and long-term, assuming short-term to mean less than 2 years. In most terrestrial ecosystems the short-term effects will be dominated by the consequences of differential sensititivities; long-term effects by these plus effects on reproductive capacity and genetic effects.

Two types of short-term effects would be expected from high level, chronic irradiation of an ecosystem: first, selective mortality of sensitive species due to direct and immediate effects of exposure; second, shifts in the relative importance of species populations through alteration of the biological interactions which normally contribute to a stable pattern of ecosystem behavior. These interactions include not only the many vaguely defined inter-plant relationships commonly lumped as "competition," but also parasite-host and predator-prey relationships. There are numerous models suggesting potential consequences of such shifts in biological interactions. Some of these have been summarized in the literature.

Research on the effects of ionizing radiation on organisms living in natural arrays is complicated by the variability of these arrays and the necessity for recognition of slight effects caused by the low-levels of exposure present. In addition, effects of exposure are usually confounded with location, making clear separation of radiation effects from other environmental influences difficult. The lowest chronic levels of ionizing radiation at which non-genetic effects on higher plants have been observed is approximately 2 r/day. Although it is probable that effects on pine stem diameter and needle growth could be observed at lower levels, perhaps 1/2 the exposure rate used for the above estimates a large factor exists between general background radiation levels and the lowest level necessary to cause a measurable effect in a sensitive plant. There is now, therefore, little reason to believe that effects can be seen in natural ecosystems except in those exposed to local fallout from experimental bomb bursts and in such ecosystems as that adjacent to the Lockheed reactor in Georgia. To produce such effects even in ecosystems containing pines, which are among the most sensitive plants known, chronic exposures in the range of 1-5 r/day would be necessary, while to produce parallel effects in oaks, minimum exposures of 10 r/day would be required. Much higher levels would be necessary tokkill these plants within a short period and to cause presently recognizable morphological effects in other more resistant species. Data have been developed indicating that environmental stress increases damage in plants caused by any level of exposure to ionizing radiation. A suggestion has been made of one mechanism explaining this effect. In any case the possibility seems to exist that exposure to ionizing radiation reduces tolerance to environmental stress and that ionizing radiation will prove limiting to survival or to normal development of plants at lower levels in irradiated ecosystems than under cultivated conditions. We would, therefore, expect to find non-genetic effects in the most sensitive plants in natural arrays at long-term exposure rates of the order of 1 r/day.

whose ?

Longer term effects of chronic exposures on organisms living in natural arrays are dependent to a higher degree on the nature of the contamination and on an additional set of biological factors. Such long-term effects are necessarily the result of exposure from both internal and external emitters and it is clear that to predict effects of exposure for any type or intensity of contamination, the mineral cycles and periods of residence of isotopes in various organisms must be known. Progress is being made in defining these cycles and their biological implications.

Less progress has been made in defining the biological considerations which are important in determining potential long-term effects. These considerations seem to be three: First, ionizing radiation is generally deleterious to living systems and exposure can be expected to reduce physiological tolerances to environmental stress. Although notable exceptions to this generality exist, especially as a result of clever genetic manipulations by man, evidence from animals and an increasing body of evidence from plants indicates strong interactions between stress and radiation exposure. It is suggested that relative sensitivity among species to this type of radiation damage probably parallels radiosensitivity shown by morphological characteristics. The extent to which this is true remains to be seen.

Second, variation in sensitivity to damage during the life cycle of an organism may be extreme, making the population as a whole much more sensitive than the mature stages of single organisms. In general reproductive processes are most sensitive to damage, vegetative or mature stages least sensitive. On the other hand, there is no threshold exposure for production of mutations.

Third, selective removal or differential inhibition of species will alter biological interactions, potentially upsetting the usual patterns of species abundance and ecosystem stability. This type of disturbance can have three forms: alteration of interspecific interactions among plants; shifts in the host-parasite balance; and shifts in predator-prey relationships. There are abundant models for these types of disturbances ranging from the removal of chestnut from the extensive oak-chestnut forests of Eastern North America by the fungus <u>Endothia parasitica</u> to numerous animal populations studies.

All of these changes produce potential instabilities in ecosystems ranging from the initiation of a new successional sequence only slightly different from the old to violent oscillations in population density which can result in extinction or in population explosions.

The research needed to elaborate these large and complex problems is itself large and complex, involving the delimitation of model systems and the analyses of these systems from numerous standpoints. Perhaps the most successful ecological study of this type is the series of studies of the spruce-budworm in Eastern Canada carried out over more than two decades and involving many scientists. Although ionizing radiation presents a different set of problems from those posed by the budworm, the Canadian work emphasizes the need for long-term, integrated approaches to such large scale and fundamental biological problems. A second type of example has been provided by chance at Rongelap Atoll and on neighboring atolls in the Pacific and at the White Oak Lake Bed at Oak Ridge. Similar examples must now exist in the Russian Arctic. Use of these examples as they are available in conjunction with experiments involving mineral cycling and the effects of internal emitters not only on organisms, but on populations and ecological systems as well, will provide at least some understanding of what is happening to the environment.

TABLE VIII

Prediction of the Sensitivity of Plants to Chronic Gamma Irradiation[1]

Percentage of the daily dose causing 100 per cent mortality (LD_{100}) required to produce various responses in plants chronically exposed to Co-60 gamma radiation

Response	Daily dose % of LD_{100}
normal appearance	<11%
10% growth reduction	26
failure to set seed	31
50% growth reduction	34
pollen sterility (100%)	41
floral inhibition or abortion	44
growth inhibition (severe)	58
LD_{50}	75
LD_{100}	100

1/ A.H. Sparrow and G.M. Woodwell, Radiation Botany, v 2, 1962: 9-26.

TABLE IX

Chronic and Acute Dosages of Co-60 Gamma Radiation at Which Various Responses Occur in Two Pines: P. Strobus and P. Rigida[1]

	P. Strobus (15 month exposure)		P. Regida (9 year exposure)		P. Strobus (brief)
Responses	r/day	total dose, r	r/day	total dose, r	gamma dose, r
Normal appearance	<2.5	1140	<1.5	3200	< 40
10% growth reduction	3-4	1370-1825	2	4250	60
Failure to set seed	-	-	5	10,600	-
Pollen sterility (100%)	-	-	3-5	6350-10,600	-
50% growth reduction	5	2280	-	-	160
Growth inhibition (severe)	10	4560	5-7	10,600-14,850	275
Lethal	20	9120	12	25,500	600

~~SECRET~~

~~SECRET~~

---

[1]

Conclusions

1. Clean weapons obviously provide a method for lowering the exposure dose to persons, animals, and plants.

2. The amount of lowering is not that predicted by merely comparing fission yields. The dose contributed by radionuclides produced within, and outside, the weapon becomes proportionately more important for "clean" as opposed to standard weapons.

3. A dose comparison on a per-weapon basis is not meaningful, because an allowance needs to be made for the spreading out of the radioactive debris following the burst, and for overlapping patterns of fallout. The mere fact that the spectrum of radionuclides changes from clean to standard weapons ensures that these environmental factors will affect comparative doses.

4. The six attack cases using all air bursts are not particularly relevant to a comparison of clean and standard weapons, for the method of damage estimation omits any contribution from the radioactive debris. These cases do present, nevertheless, a benchmark against which the possible advantages of clean weapons can perhaps better be evaluated. The air burst cases give a sort of limiting picture of minimal casualties and fatalities, and - by assumption - exposure levels (zero).

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

6. Clean weapons lead to reduced fatalities and casualties for surface bursts, especially in the larger attacks. The same is true for livestock

fatalities. Interestingly, the livestock-to-person ratio runs about constant. This is not too surprising from the methods of approach used in this study. Very roughly, the people and the agriculture and the military targets of the U.S.S.R., and of course the industrial targets, are in the same parts of the country, considering the vast relatively unused land area.

7. The survivors of the clean-weapon attacks very clearly survive with a lower lifetime gamma exposure dose - a factor relevant to the subsequent state of their health.

8. Clean weapons expose the plant life to lower doses. How important this is depends on the application. For example, crop damage may be lessened from the clean attacks, but on the other hand more people survive who will demand food.

9. We have looked, for each attack situation (surface burst) at the fictitious contours defining the most highly contaminated 10% of the U.S.S.R. agricultural cropland, and the 25% contour. Thus we are talking about 1/10 and 1/4 of the cropland (not of the total U.S.S.R. land area), which ensures that we do not devote too much attention to very small but highly contaminated areas. The maps (DODDAC REPORT, p. 261ff) show qualitatively that if criteria of acceptable or unacceptable hazard are applied to these two fictitious contours with judgment, we are not likely to come to wrong conclusions about the consequences of the attack cases studied.

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

[redacted]

11. The biologically significant internal emitters from fission are, of course, reduced in quantity by the ratio of fission yields in the clean attacks compared with the standard-weapon attacks. Neutron-induced activity in soil is about comparable.

FOIA(b)(3) - 42 USC 2162(a) - RD DOE EO13526 6.2(a)

12. According to present methods of estimation, rad doses to the thyroid from the ingestion of I-131 can run from thousands to hundreds of thousands of rads. But these methods ignore the possibility of even elementary countermeasures. The higher end of the rad dose range numerically estimated is unlikely to occur because survival of the milk cows is unlikely. For this study, it has not been possible to correct the I-131 dose estimate for this factor, because it is not clear what the livestock survival is in any specific region where the contamination level is high, in relation to survival elsewhere.

13. If the population had better shelter than that assumed in the DODDAC REPORT, it is possible that the internal emitter dose would become relatively much more important, compared to the external gamma dose. If one wished to reduce the internal emitter dose, the advantage of clean weapons is obvious; but such a goal is not necessarily meaningful if the population is not well sheltered.

14. From the point of view of occupancy of the U.S.S.R. by U. S. troops

(using their own food supplies), two characteristics of clean weapons stand out:

a. The external gamma dose is less, for a given attack, by about a factor of 5 to 10

b. This dose is delivered relatively faster, so that if troops do not occupy the U.S.S.R. land area until about 100 to 500 hours post-attack, the dose left to be delivered is very small (DODDAC REPORT, p. 69).

c. Shelter occupancy times - to keep the accumulated dose below a preselected value - would be shorter for the clean weapons.

15. (A short statement about the world-wide fallout will be inserted.)

16. Insofar as (i) external gamma dose effects on plants, and (ii) levels of internal emitters are concerned, it is difficult to believe that either factor will be limiting to agriculture in an absolute sense. Either the situation will be so bad that other factors (such as availability of equipment, or of farmers) will be limiting, or else some sort of countermeasures will begin to be worth considering. This remark does not, of course, mean to cover such possibilities as real ecological devastation from the combined effects of fire, radiation, and selective biological depletion and enrichment of species. But, as discussed in this report, these questions are far beyond our present understanding.

NATIONAL
SECURITY
ARCHIVE

National Security Archive,

Suite 701, Gelman Library, The George Washington University,

2130 H Street, NW, Washington, D.C., 20037,

Phone: 202/994-7000, Fax: 202/994-7005, nsarchiv@gwu.edu