Evaluation of the Influence of the Physico-Chemical Form of ^{131}I on the Thyroid Dose Estimates

Contents

oid dose estimates that are calculated in the report are the assumption that ^{131}I in the radioactive cloud is only n particulate form. This appendix addresses the question ference in the estimated doses that may have resulted simplifying assumption. The alternative approach ave been to make more complex calculations that he behavior of various forms explicitly.

KGROUND AND ASSUMPTIONS

sico-chemical forms of airborne ^{131}I can be classified

iodine associated with particles
molecular (I_2)
organic (such as CH_3I).

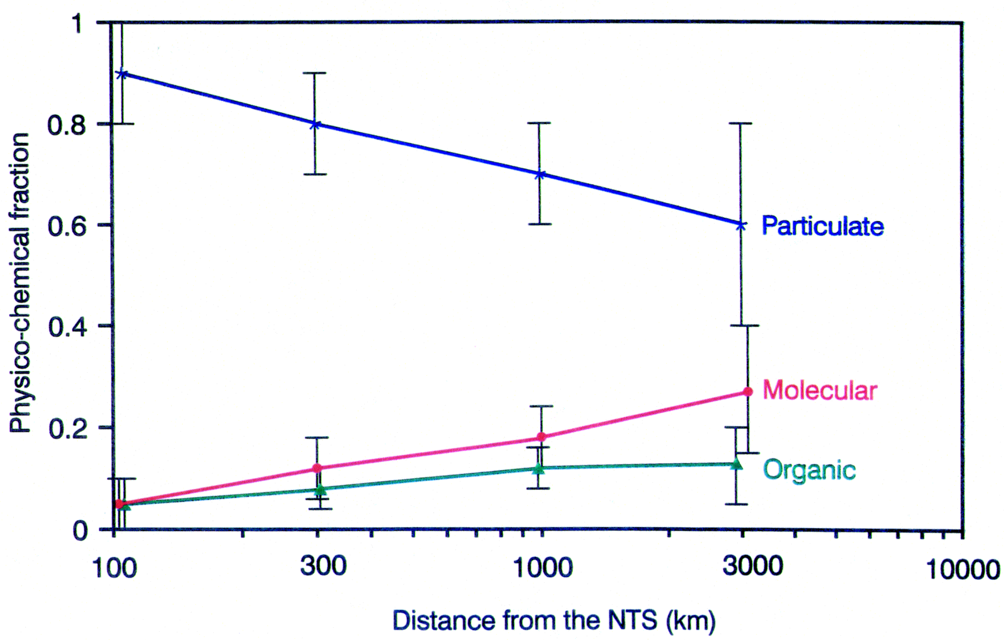
is thought that:

Most of the ^{131}I was in particulate form close to the NTS. There was a broad range of particle sizes soon after detonation. As the radioactive cloud moved away from the NTS, the inventory of large particles was progressively depleted due to deposition. The median particle size in the cloud decreased with increasing travel time and distance from the NTS. Simultaneously, chemical reactions produced organic and molecular forms.

- The fractions of elemental iodine and organic form were small in the initial radioactive cloud but beca larger with increasing time since detonation (or at greater distances from the NTS).

On the basis of observations of fallout from Chinese weapons tests in recent years for long distances from the N (Voilleque 1979) and on measurements following the Baneb event of December 1970 for short distances from the NTS (1972; Pendleton et al. 1971), the relative distribution of the physico-chemical forms (PCF) considered is assumed to va function of distance X from the NTS as shown in *Figure A7.* in *Table A7.1*.

7.1. Relative distribution of the physico-chemical forms of ^{131}I according to distance from the NTS. (The vertical bars represent the assumed ranges of uncertainty)



.1. Best estimates and ranges of the fractions of ^{131}I associated with particles, in molecular form, and inorganic form, according to distance, X, from the NTS.

chemical form	X = 100 km		X = 300 km		X = 1000 km		X = 3000 km	
	Estimated values		Estimated values		Estimated values		Estimated values	
	Best	Range	Best	Range	Best	Range	Best	Range
:e	0.9	0.8-1.0	0.8	0.7-0.9	0.7	0.6-0.8	0.6	0.4-0.8
r	0.05	0-0.1	0.12	0.06-0.18	0.18	0.12- 0.24	0.27	0.15-0.4
	0.05	0-0.1	0.08	0.04-0.12	0.12	0.08-0.16	0.1	0.05-0.2

or the purposes of the uncertainty analysis, the statistical ons of the molecular and organic form fractions are to be uniform within the specified ranges. In the calcu- ɔcedure, the fraction of ^{131}I associated with particles is by subtraction of the sum of the values for the molecu- rganic forms; its statistical distribution is observed to be ıately triangular.

THOD

ɔid doses arise from inhalation of ^{131}I-contaminated air gestion of ^{131}I-contaminated foodstuffs. A comparison of .oses obtained when ^{131}I is only in particulate form and I is distributed among various physico-chemical forms is ɔ determine whether the dose estimates calculated under ıssumptions are greatly different. Because most of the .ose is proportional to the deposition density of ^{131}I on n (also called "^{131}I vegetation deposition density" in this :), and since the relationship between the thyroid dose ^{31}I vegetation deposition density is independent of the :hemical form of ^{131}I, the comparison of the dose esti- :o a large extent equivalent to the comparison of the n densities of ^{131}I on vegetation.

ıe comparison of the ^{131}I vegetation deposition densities when ^{131}I is only in particulate form and when ^{131}I is :d among various physico-chemical forms was carried unit time-integrated concentration of ^{131}I in ground- (IC_{air}) of 1 nCi d m^{-3} (equivalent to an average concen- ^{131}I in ground-level air of 1 nCi m^{-3} over 1 day).

ıe parameters influenced by the physico-chemical form :e:

the dry deposition velocity, v_g,

the washout ratio, WR,

the mass interception factor, F*

The calculations of the vegetation deposition densiti were performed for the following conditions:

- 4 distances X from the NTS: 100 km
  300 km
  1000 km
  3000 km

- dry deposition and wet deposition for eight values daily rainfall, R, that are representative values for precipitation index (*Table A7.2*).

- 3 physico-chemical forms (particles (P), molecular and organic (ORG)), the relative distributions of w are assumed to vary as a function of distance from NTS as described above (see *Figure A7.1*).

The vegetation deposition density, A_p in nCi m^{-2}, is t product of the deposition density on the ground, DG in nC and of the interception fraction, F:

$$A_p = DG \times F$$

The deposition density on the ground is:

- under dry conditions, obtained as the product of t time-integrated concentration in ground-level air, I and of the dry deposition velocity, v_g:

$$DG_{dry} = IC_{air} \times v_g$$

where:

IC_{air} = 1 nCi d m^{-3}

v_g is expressed in m d^{-1}

amount of daily rainfall, R, and the density of the air at ·vel, AD:

$$DG_{wet} = IC_{air} \times R \times \frac{WR}{AD} \quad (A7.3)$$

R is the ratio of the time-integrated concentrations of ^{131}I in rain and in air, expressed in $(nCi\ d\ kg^{-1})(nCi\ d\ kg^{-1})^{-1}$

is the density of air at ground level = 1.2 kg m^{-3}

ıe total deposition density on the ground, DG_{tot} is the ıe depositions due to dry and wet processes:

$$G_{tot} = DG_{dry} + DG_{wet} = IC_{air} \times \left(V_g + \frac{(R \times WR)}{AD}\right) \quad (A7.4)$$

ıe interception fraction is the product of the mass inter- actor, F*, and of the biomass, Y:

under dry conditions:

$$F_{dry} = F^*_{dry} \times Y \quad (A7.5)$$

for deposition with rain:

$$F_{wet} = F^*_{wet} \times Y \quad (A7.6)$$

F^*_{dry} and F^*_{wet} are the mass interception factors for dry and wet respectively, expressed in $m^2\ kg^{-1}$ (dry weight of vegetation).

The estimates of the vegetation deposition densities given physico-chemical forms, daily rainfalls, and distanc the NTS, are derived from *equations A7.1* to *A7.6*:

- under dry conditions:

$$A_{p,\,dry}(X, R, PCF) = IC_{air} \times v_g(X, PCF) \times F^*_{dry}(X, PCF) \times Y$$

- deposition with rain:

$$A_{p,\,wet}(X, R, PCF) = IC_{air} \times R \times WR(X, R, PCF) \times F^*_{wet}(X, PCF) \times$$

- for the total deposition:

$$A_{p,\,tot}(X, R, PCF) = A_{p,\,dry}(X, PCF) + A_{p,\,wet}(X, R, PCF)$$

.2. Daily rainfalls associated with each precipitation index.

·ather conditions	Precipitation, indices and amounts		Representative daily rainfall (mm, L/m² or Kg/m²)
	Index	Daily rainfall range (mm, L/m² or Kg/m²)	
Dry	1	0	0
Wet	2	> 0 - 0.25	0.15
Wet	3	> 0.25 -0.76	0.5
Wet	4	> 0.76 - 2.5	1.5
Wet	5	> 2.5 - 7.6	5
Wet	6	> 7.6 - 25	15
Wet	7	> 25 -76	50
Wet	8	> 76 - 127	100
Wet	9	> 127	150

ıe-integrated concentration in air of ^{131}I with the mix of physico-chemical forms, $A_{p,tot}(X,R,MIX)$, is by weighting the results calculated for each physico- form according to the fraction FR(PCF) of ^{131}I in each :hemical form:

$$MIX) = A_{p,\,tot}\,(X, R, P) + A_{p,\,tot}\,(X, R, M) + A_{p,\,tot}\,(X, R, ORG)$$

$$= IC_{air} \times Y \times \Big[\Big(FR(P) \times v_g\,(X, P) \times F^*_{dry}\,(X, P)\Big)$$

$$+ \Big(FR\,(M) \times v_g\,(X, M) \times F^*_{dry}\,(X, M)\Big)$$

$$+ \Big(FR\,(ORG) \times v_g\,(X, ORG) \times F^*_{dry}(X, ORG)\Big)$$

$$+ \left(\frac{R}{AD}\right) \times \Big(FR\,(P) \times WR\,(X, R, P) \times F^*_{wet}\,(X, P)\Big)$$

$$+ \Big(FR\,(M) \times WR\,(X, R, M) \times F^*_{wet}\,(X, M)\Big)$$

$$+ \Big(FR\,(ORG) \times WR\,(X, R, ORG) \times F^*_{wet}\,(X, ORG)\Big)\Big] \qquad (A7.10)$$

IMATES OF THE PARAMETER VALUES

Ͻry Deposition Velocity

ɭeposition velocity can be experimentally defined as the of the activity deposited per unit area of ground and of integrated concentration in ground-level air in the ɔf precipitation.

. Fraction associated with particles

ɭeposition velocity for particles depends on the particle ;e particles (greater than 20 µm in diameter) are from the air mainly by sedimentation; smaller particles nged from the air by impaction and turbulent diffusion. formation on particle sizes in ground-level air near the ɔwing atmospheric tests is available mostly for the Knothole series (Cederwall et al. 1990). Activity median mic diameters (AMADs) and geometric standard devia- ›Ds) for particle-size distributions observed in St. JT, situated approximately 200 km from the NTS are ı *Table A7.3* for the tests Annie and Harry. The results : are much more typical of the tests sampled in the Knothole series than those for Harry (Cederwall et al. ırticle size distributions for both tests are characterized ırge GSD values and AMAD values that tended to with time.

ssuming that the upper and lower values of the ranges e sizes are adequately represented by the values by multiplying and dividing the median estimates by ɾe of the GSDs, the particle-size spectrum is from 0.15 3,000 µm at 200 km from the NTS.

turn reflected in the estimates of dry deposition velocity ne NTS. Cederwall et al. (1990) identified several locations w 320 km of the NTS where paired values of the time-integra concentration in air and the deposition density are availabl a number of tests. The resulting estimates of v_g from 168 p values varied over several orders of magnitude with a geon mean of 3700 m d^{-1} and a GSD of 15. This extremely large value may be partly due to the fact that the data were not s fied according to downwind distance from the NTS or to lo tion relative to the fallout-pattern centerline. In addition, t deposition density and the time-integrated concentration in may have been measured in the same general area but not ly at the same site.

Beyond 320 km of the NTS, the average particle siz expected to be smaller, resulting in turn in smaller deposit velocities. A geometric mean of 2500 m d^{-1} with a GSD of was obtained from 52 pairs of air samples and deposition (related to the Tumbler-Snapper series (List 1953).

Dry deposition velocities at greater distances from tl NTS have been derived from air concentrations and depos measurements by Pelletier and Voilleque (1971) of fallout a from tests conducted in the Pacific and in territories of the mer Soviet Union. The measurements took place in Michig from 1962 to 1964. A distinction was made between fresh out (defined by the presence of measurable quantities of ^{14} air) and old fallout (absence of ^{140}Ba in air). According to t criterion, measurements in the contiguous U.S. following nuclear testing at the NTS would have been defined as fre fallout. The average values of v_g were computed from meas ments to be 1000 m d^{-1} during periods of fresh fallout and m d^{-1} during periods of old fallout (Pelletier and Voilleque 1971), showing presumably the effect of smaller particle si for old fallout. The GSDs associated with the results were r reported but the values of v_g during periods of fresh fallou indicated to be quite variable from week to week.

On the basis of the experimental values that have be reported, the variation with distance from the NTS of the a age values of $v_g(X,P)$ for ^{131}I associated with particles is fou be relatively well modeled with a power function. The em function that has been adopted is:

$$v_g\,(X, P) = 20150 \times X^{-0.35}$$

where

$v_g(X,P)$ is in m d^{-1}, and X is in km.

The distribution of $v_g(X,P)$ is assumed to be log-tria for the four distances considered with the spread of values decreasing with distance as shown in *Table A7.4*. For the d tance closest to the NTS, X = 100 km, the distribution of v is assumed to have a mode equal to the best estimate and a range from 400 to 200,000 m d^{-1}. This distribution corres approximately to the central portion (20th to 80th percent of a log-normal distribution with a GSD of 7. Deposition v ties of 400 m d^{-1} or less are associated with very small fallo sition velocities at other distances as well. The indicated 1 the modal and maximum deposition velocities with is intended to reflect the depletion of large particles cloud. The assumed variation of the modes and ranges of the dry deposition velocity for ^{131}I associated with as a function of the distance from the NTS, is illustrated A7.2.

. Molecular fraction

deposition velocities for the molecular fraction of iodine ally been derived from field experiments in which mea- s have been made of the time-integrated concentration l of the activity deposited on vegetation cut at between m above ground. The dry deposition velocities obtained ay are smaller than those derived from measurements of activity deposited on the ground since the additional n on the remaining vegetation, detritus, root mat, and not been included. Vegetation deposition velocities for r iodine vary as a function of meteorological parameters eed, air temperature, and humidity) and of the biomass; and Sauve (1981) suggested that the vegetation deposi- sity is proportional to the biomass and to the wind speed eases by a factor of 2 for a temperature increase of 10ºC rease in the relative humidity of 25%.

order to avoid confusion between the two quantities on deposition velocity and total deposition velocity) and e the influence of the biomass, Hoffman (1977) recom- that the vegetation deposition velocity should be nor- or biomass (dry weight per square metre of ground). nalized vegetation deposition velocity v_D is expressed in rt in $m^3\ kg^{-1}\ d^{-1}$ and is related to the dry deposition ccording to:

$$v_D = v_g \times F^* \qquad (A7.12)$$

Zimbrick 1970; Vogt et al. 1976), Hoffman (1977) estimate a value for v_D of 0.1 $m^3\ kg^{-1}\ s^{-1}$ is suitable for a generic asse ment calculation; the same value, which corresponds to 90 $kg^{-1}\ d^{-1}$, is adopted in this report. The distribution of $v_D(M)$ assumed to be log-normal with a GSD of 2.0, at all downw distances.

A7.4.1.3. Organic fraction

The major organic form of iodine that is found in the atmo after a nuclear test is methyl iodide (CH_3I). Methyl iodide i that deposits on vegetation to a much smaller degree than c molecular iodine. The ratio of the vegetation deposition vel (or of the normalized vegetation deposition densities) of m lar and organic iodine has been reported to be approximate 100 (Nakamura and Ohmomo 1980a; Nakamura and Ohn 1980b) and 200 (Heinemann and Vogt 1980). In this repor average ratio of 150 has been used, corresponding to a nor ized vegetation deposition velocity for organic iodine, v_D(O of 9000/150 = 60 $m^3\ kg^{-1}\ d^{-1}$. This value is assumed to be i pendent of distance from the NTS. The distribution of v_D(C is also assumed to be log-normal with a GSD of 2.0.

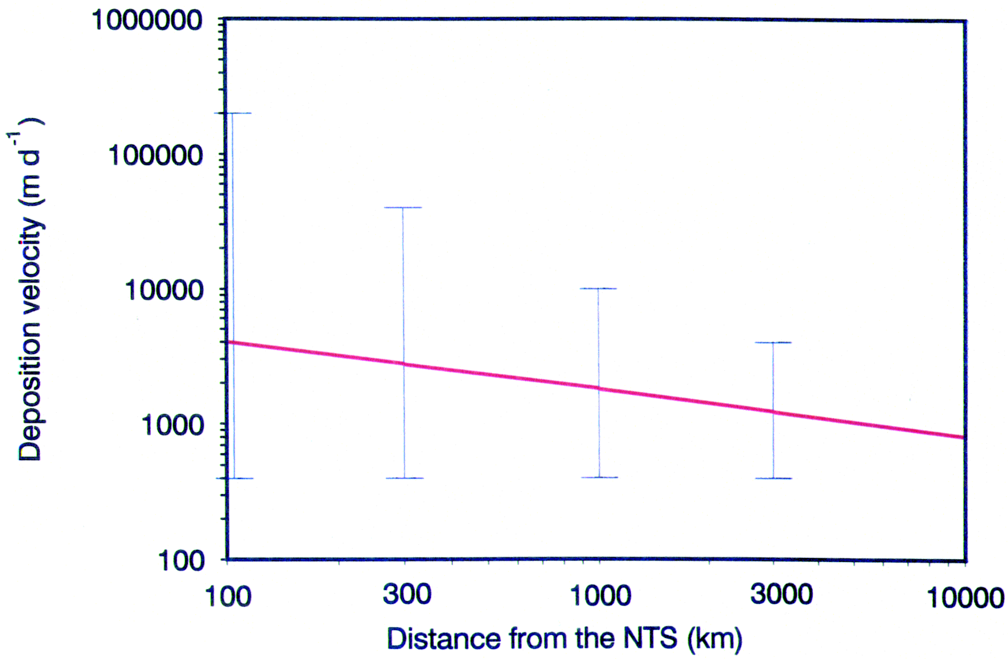
A7.4.2. Washout Ratio

The washout ratio, WR, is the ratio of the concentration of rain to that in air at ground level. The washout ratio is dim sionless but it has a different value according to whether th centrations are expressed per unit mass or per unit volume. this report, the concentrations are expressed per unit mass kg^{-1}).

.3. Variation of particle size with time at St. George, UT, for the tests Annie and Harry of the Upshot-Knothole series (Cederwall et al. 1990).

Test Annie, 1320 GMT, 17 March 1953			Test Harry, 1205 GMT, 19 May 1953		
times,GMT	AMAD (μm)	GSD	Sample times, GMT	AMAD (μm)	GSD
20	76	9	1310-1830	380	10
10	24	8	1840-2145	160	8
00	7.3	7	2150-0600	320	9
			0605-1335	12	6

7.2. Assumed variation of the dry deposition velocity (m d^{-1}) according to distance from the NTS, for ^{131}I associated with particles. (The vertical bars rep sent the assumed ranges of uncertainty)



.4. Variation of the dry deposition velocity of ^{131}I associated with particles according to distance, X, from the NTS.

km)	Type of distribution	v_g (X,P) (m d^{-1})		
		Minimum	Mode	Maximum
00	Log-triangular	400	4000	200,000
300	Log-triangular	400	2700	40,000
000	Log-triangular	400	1800	10,000
000	Log-triangular	400	1200	4,000

iout ratio for particles has been found to increase with ize (Gatz 1977). Increasing the rainfall rate at a particu- vill lead to an increase in washout at that moment '78). However, washout ratios for ^{90}Sr measured for ıl storms decreased when the total amount of rain for ı increased (Krey and Toonkel 1977). A similar trend d when the washout ratio was plotted against the precipitation (Krey and Toonkel 1977). Gatz (1977) d a negative correlation with storm rainfall for washout most of the elements measured, but the trends were not gnificant when analyzed statistically.

or the present analysis, washout ratios that are consis- the previous analysis of scavenging factors and relative of wet and dry deposition for U.S. locations have been (**Chapters 3** and **7** and **Appendix 1**). Two reference ere selected: (a) 13000 for a daily rainfall amount of 1 for large particles (X = 100 km); and (b) 3000 for a ıfall amount of 1 mm and for small particles (X = 3000 ues for other situations were derived from the reference

for a given distance, X, as a function of daily rainfall, R:

$$WR\ (X, R, P) = WR\ (X, 1\ mm\ d^{-1}, P) \times R^{-0.7} \qquad (A7.13)$$

for a given daily rainfall, R, as a function of distance X:

$$WR\ (X, R, P) = WR\ (100\ km, R, P) \times \left(\frac{X}{100}\right)^{-0.43} \qquad (A7.14)$$

ıe washout ratios obtained in this way are shown in .3 for ^{131}I associated with particles and in *Figure A7.4* ı molecular and organic forms, for a distance from the 00 km and for the range of daily rainfall considered in rt. The higher washout ratios near the NTS reflect the of larger particles in the radioactive cloud. The ratios more sharply with daily rainfall than the results report- ey and Toonkel (1977) for monthly averages or by Gatz

. *Molecular fraction*

es of WR(R,M) for ^{131}I in molecular form are indepen- ıe distance, X, from NTS. However, they are also to decrease with rainfall amount (Coleman and Postma reference value of 6000 was selected for a daily rainfall of 1 mm, based on the partition coefficient estimate of 1970) and typical airborne iodine concentrations. r other rainfall amounts were derived from the refer- ıe using the same decrease with daily rainfall as for the

The values of WR(R,ORG) for ^{131}I in organic form also are independent of the distance, X, from NTS. Based on the di ence in partition coefficients (Postma 1970), the reference for a daily rainfall of 1 mm is taken to be 10. The variation function of daily rainfall has been assumed to be the same that described above for particles and for elemental iodine.

A7.4.2.4. Summary

Table A7.5 summarizes the best estimates of the washout r expressed in (nCi kg^{-1})(nCi kg^{-1})$^{-1}$, for the three species of and the four distances considered in this report. *Table A7.5* includes the range of washout ratio values that is expected each case. At a given distance from the NTS, for a given ph co-chemical form and rainfall category, the lowest value (m mum) of the washout ratio is assumed to be equal to the b estimate in the next category of higher rainfall, while the h value (maximum) is assumed to be equal to the best estima the adjacent category of lower rainfall. In rainfall category (O<R<0.25 mm), the maximum value was taken to be twic mode. In rainfall category 9 (R>127 mm), the minimum va was taken to be the mode divided by 1.5. The distribution the wash-out ratios in each category is assumed to be trian the mode being equal to the best estimate.

*A7.4.3. Mass Interception Factor, F**

The mass interception factor represents the quotient of the radionuclide concentration in vegetation (dry weight) and ground deposition density, immediately after deposition. It ues are expressed in m^2 kg^{-1}(dry). The mass interception fa is denoted as F^*_{dry} and as F^*_{wet} for deposition under dry an wet conditions, respectively.

A7.4.3.1. Fraction associated with particles

Values of F^*_{dry} and F^*_{wet} for particles are calculated using t following equations, which are discussed in **Chapter 4:**

- Dry deposition (F dry):

$$F^*_{dry}\ (X, P) = \frac{1 - e^{\alpha(x)Y}}{Y}$$

with

$$\alpha(X) = 7.01 \times 10^{-4}\ x^{1.13}$$

and

$$Y = 0.3\ kg\ m^{-2},\ dry\ weight.$$

2.8 m^2 kg^{-1}, which is met for any distance X greater
40 km.

Wet deposition ($R \geq 5$ mm d^{-1}) (F^*_{wet}):

$$F^*_{wet}(R, P) = 0.9 + \left(\frac{11}{R}\right) \quad (A7.17)$$

espective of the distance X from the NTS (i.e., no
nce on the particle size is considered).

Wet deposition (2.5 mm d^{-1} < R < 5 mm d^{-1}):

$$F_{wet}(R, P) = F^*_{wet}(5\ mm\ d^{-1}) = 3.1\ m^2\ kg^{-1} \quad (A7.18)$$

espective of the distance X from the NTS (i.e., no
nce on the particle size is considered).

Wet deposition (R < 2.5 mm d^{-1}):

$$(X, R, P) = F^*_{dry}(X, P) + (F^*_{wet}(R_1, P) - F^*_{dry}(X, P))\left(\frac{R}{R_1}\right) \quad (A7.19)$$

$= 2.5$ mm d^{-1}.

. *Molecular fraction*

F^*_{dry} for the molecular fraction are not needed as the n of the vegetation deposition density for that physico- form make use of the normalized vegetation deposition which is the product v_g x F^*_{dry}. In case of precipitation, s of F^*_{wet} for ^{131}I in molecular form are assumed to be smaller than the values obtained for particles far away NTS (Hoffman et al. 1989).

. *Organic fraction*

F^*_{dry} for the organic fraction are not needed for the son as for the molecular fraction. Values of F^*_{wet} for ^{131}I c form are assumed to be equal to the values used for olecular form.

. *Summary*

6 summarizes the estimated values of the mass inter- actor. Hoffman and Baes (1979) found that the values ass interception factor for dry conditions are log-nor- tributed with a geometric standard deviation of 1.5. In rt, the distribution of the values of the mass intercep- or is assumed to be log-normal with a geometric stan- iation of 1.5, for all physico-chemical forms, daily rain- distances from the NTS.

ciated with particles is illustrated:

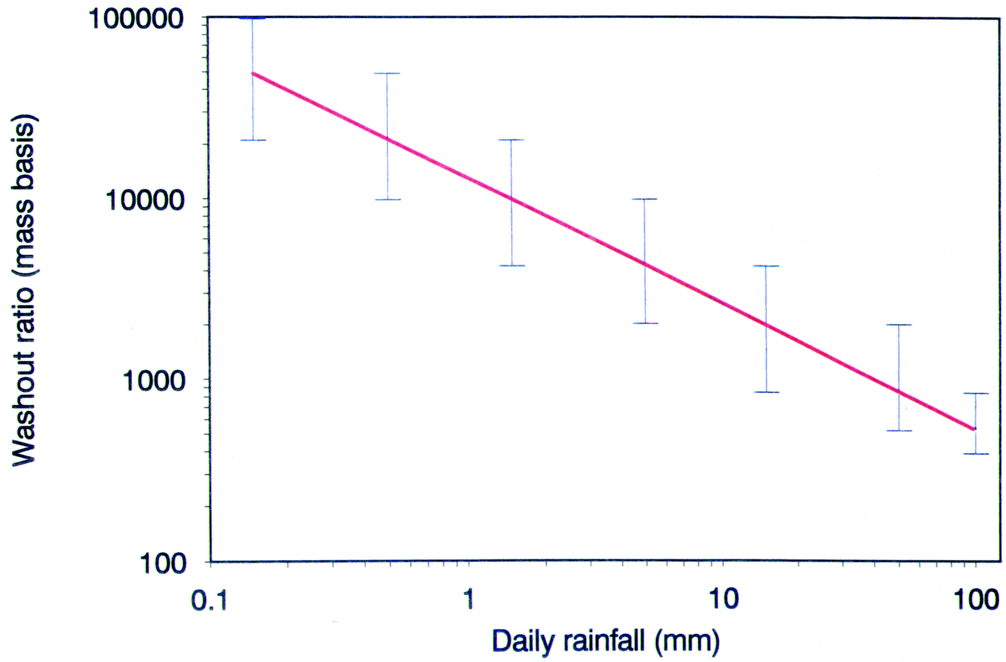
- as a function of distance from the NTS (in the abs of rain) in *Figure A7.5,*
- as a function of daily rainfall in *Figure A7.6.*

A7.5. RESULTS

Vegetation deposition densities have been calculated using *tions A7.1* to *A7.4*. The calculations have been made in a st tic manner, using the distributions indicated previously for parameter. All parameters have been assumed to be indepe dent, with the exception of the dry deposition velocity, v_g(X and the mass interception factor, F^*_{dry}, for iodine associate with particles at the closest distance from the NTS (X = 10 km). The distributions of the vegetation deposition densiti have been calculated for two sets of physico-chemical form ^{131}I : (a) uniquely associated with particles, and (b) distribu among particulate, elemental, and organic forms as shown *Table A7.1. Table A7.7* presents the estimated median values well as the 5 and 95 percentiles, of the vegetation depositi density, A_p in nCi m^{-2}, corresponding to a unit time-integra concentration in air of 1 nCi d m^{-3}. The values estimated fo attached to particles and for the assumed mixture of physi chemical forms, are shown in *Figures A7.7* and *A7.8* for dis of 100 and 3000 km downwind from the NTS, respectivel

The medians of the ratios of the vegetation depositi densities obtained when ^{131}I is distributed among the three physico- chemical forms and when ^{131}I is attached to parti $\langle A_p(mix) / A_p(P) \rangle$, are presented in *Table A7.7* along with t and 95 percentiles of the distributions. The ratios obtained distances of 100 and 3000 km downwind from the NTS ar illustrated in *Figure A7.9.*

7.3. Variation of the washout ratio as a function of daily rainfall for ^{131}I associated with particles, for a distance of 100 km from the NTS. (The vertical bars represent the assumed ranges of uncertainty)



7.4. Variation of the washout ratio as a function of daily rainfall for ^{131}I in molecular and organic form .
(The vertical bars represent the assumec ranges of uncertainty)

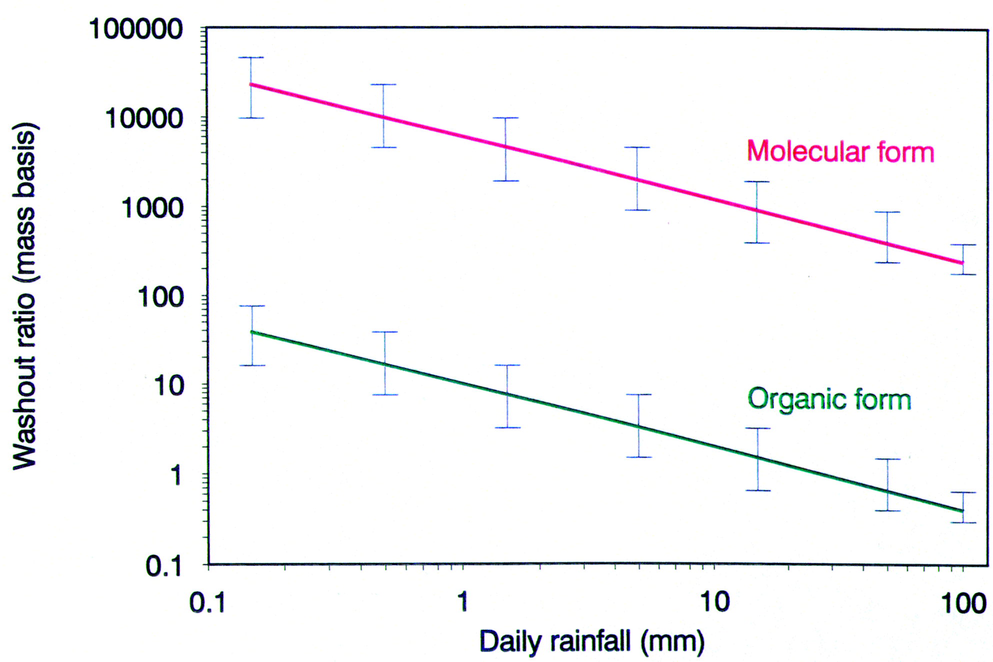


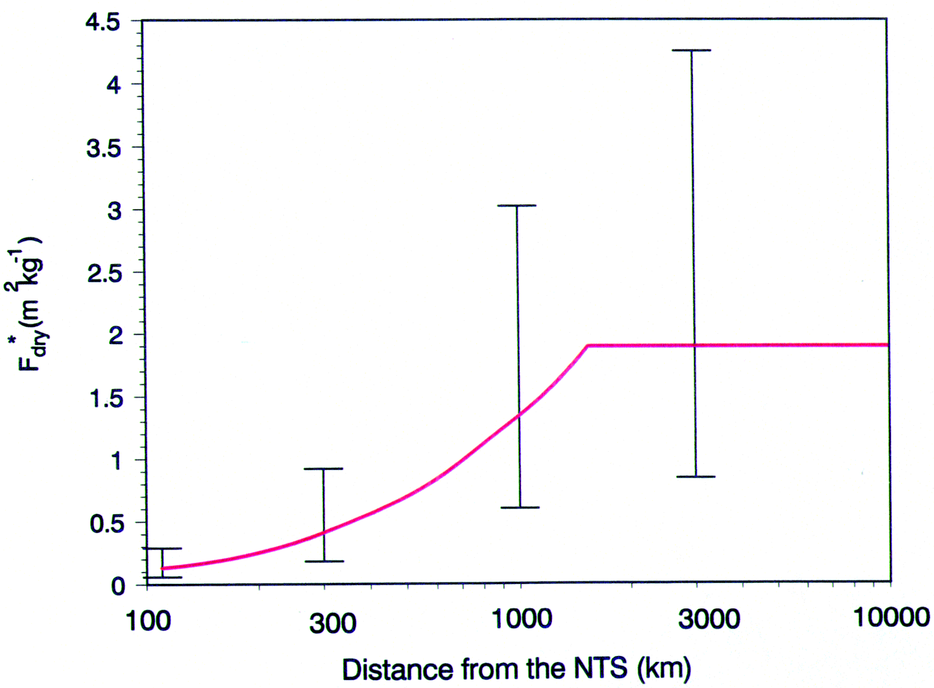
Table A7.5. Best estimates and ranges of wash-out ratios. WR {(nCi kg^{-1}) (nCi $(kg^{-1}))^{-1}$} for ^{131}I in the 3 physico-chemical forms and the 4 distances from the NTS, X (km), considered.

Prec. index	Daily rain	Particulate			Molecular			Organic		
	mm	Min.	Mode	Max.	Min.	Mode	Max.	Min.	Mode	Max
X = 100 km										
2	0.15	21000	49000	98000	9700	23000	46000	16	38	76
3	0.5	9800	21000	49000	4500	9700	23000	7.5	16	38
4	1.5	4200	9800	21000	1900	4500	9700	3.2	7.5	16
5	5	2000	4200	9800	900	1900	4500	1.5	3.2	7.5
6	15	840	2000	4200	390	900	1900	0.65	1.5	3.2
7	50	520	840	2000	240	390	900	0.40	0.65	1.5
8	100	390	520	840	180	240	390	0.30	0.40	0.65
9	150	260	390	520	120	180	240	0.20	0.30	0.40
X = 300 km										
2	0.15	13000	31000	62000	9700	23000	46000	16	38	76
3	0.5	6100	13000	31000	4500	9700	23000	7.5	16	38
4	1.5	2300	6100	13000	1900	4500	9700	3.2	7.5	16
5	5	1200	2600	6100	900	1900	4500	1.5	3.2	7.5
6	15	520	1200	2600	390	900	1900	.065	1.5	3.2
7	50	320	520	1200	240	390	900	0.40	0.65	1.5
8	100	240	320	520	180	240	390	0.30	0.40	0.65
9	150	160	240	320	120	180	240	0.20	0.30	0.40
X = 1000 km										
2	0.15	7800	18000	36000	9700	23000	46000	16	38	76
3	0.5	3600	7800	18000	4500	9700	23000	7.5	16	38
4	1.5	1600	3600	7800	1900	4500	9700	3.2	7.5	16
5	5	720	1600	3600	900	1900	4500	1.5	3.2	7.5
6	15	310	720	1600	390	900	1900	0.65	1.5	3.2
7	50	190	310	720	240	390	900	0.40	0.65	1.5
8	100	140	190	310	180	240	390	0.30	0.40	0.65
9	150	90	140	190	120	180	240	0.20	0.30	0.40
X = 3000 km										
2	0.15	4900	11000	22000	9700	23000	46000	16	38	76
3	0.5	2300	4900	11000	4500	9700	23000	7.5	16	38
4	1.5	980	2300	4900	1900	4500	9700	3.2	7.5	16
5	5	450	980	2300	900	1900	4500	1.5	3.2	7.5
6	15	190	450	980	390	900	1900	0.65	1.5	3.2
7	50	120	190	450	240	390	900	0.40	0.65	1.5
8	100	90	120	190	180	240	390	0.30	0.40	0.65
9	150	60	90	120	120	180	240	0.20	0.30	0.40

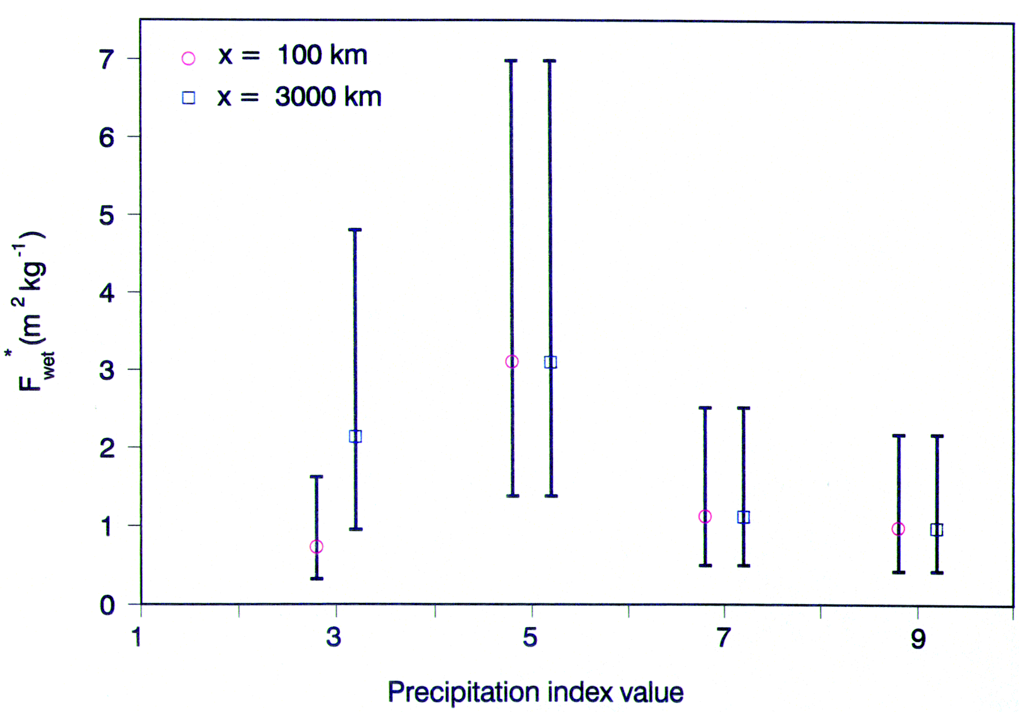
.6. Best estimates of the mass interception factors, F^*_{dry} and F^*_{wet}, in $m^2\ kg^{-1}$ (dry).

o- chemical form	Precip. Index value	Distance from the NTS (km)			
		100	300	1000	3000
		F^*_{dry} ($m^2\ kg^{-1}$)			
Particles	1	0.13	0.41	1.34	1.89
Molecular	1				
Organic	1				
		F^*_{wet} ($m^2\ kg^{-1}$)			
Particles	2	0.30	0.57	1.45	1.97
	3	0.72	0.95	1.70	2.14
	4	1.91	2.03	2.40	2.62
	5	3.10	3.10	3.10	3.10
	6	1.63	1.63	1.63	1.63
	7	1.12	1.12	1.12	1.12
	8	1.01	1.01	1.01	1.01
	9	0.97	0.97	0.97	0.97
cular or Organic	2	0.20	0.20	0.20	0.20
	3	0.21	0.21	0.21	0.21
	4	0.26	0.26	0.26	0.26
	5	0.31	0.31	0.31	0.31
	6	0.16	0.16	0.16	0.16
	7	0.11	0.11	0.11	0.11
	8	0.10	0.10	0.10	0.10
	9	0.10	0.10	0.10	0.10

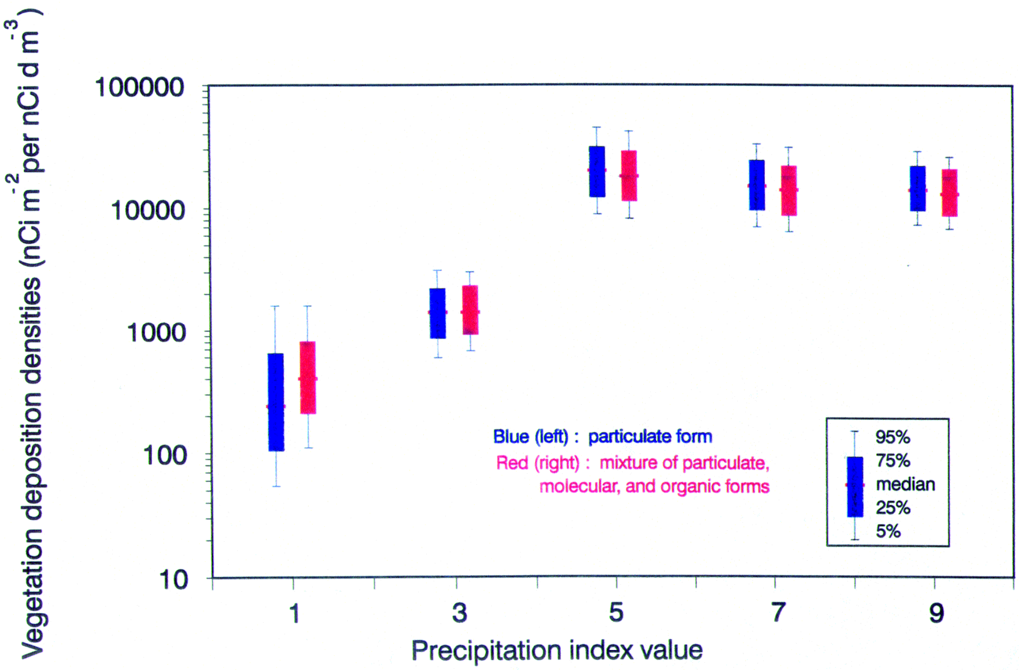
7.5. Variation of the mass interception factor (dry conditions), in m² kg⁻¹, as a function of distance from the NTS for ^{131}I associated with particles (the ver cal bars represent 95% confidence intervals).



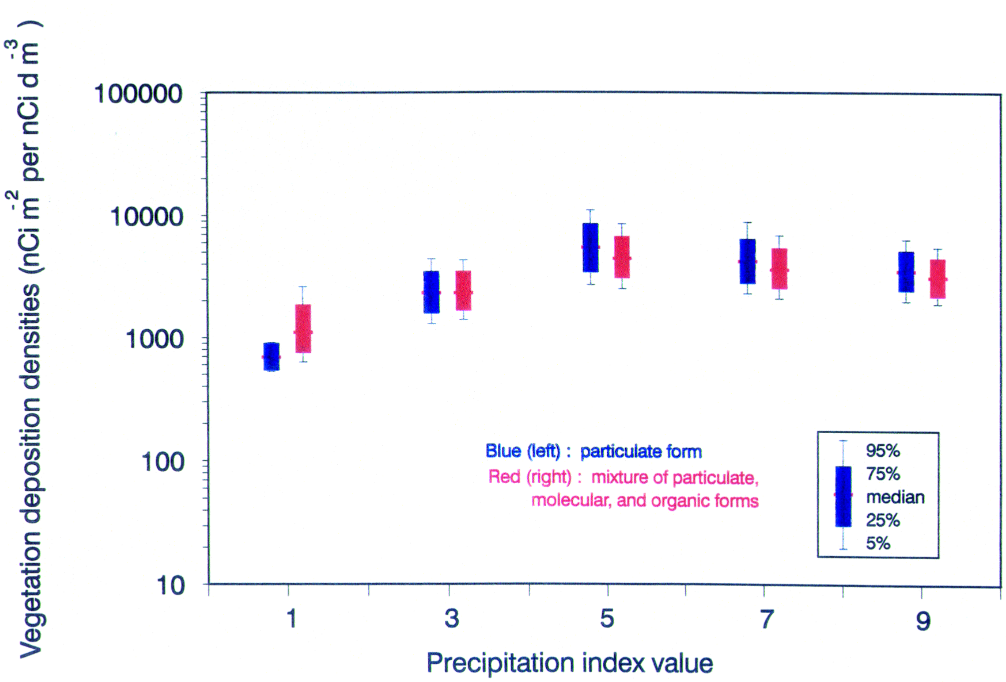
7.6. Variation of the mass interception factor according to the precipitation index value for ^{131}I attached to particles and 2 distances from the NTS. (Media and 95% confidence intervals are shown on the vertical bars)



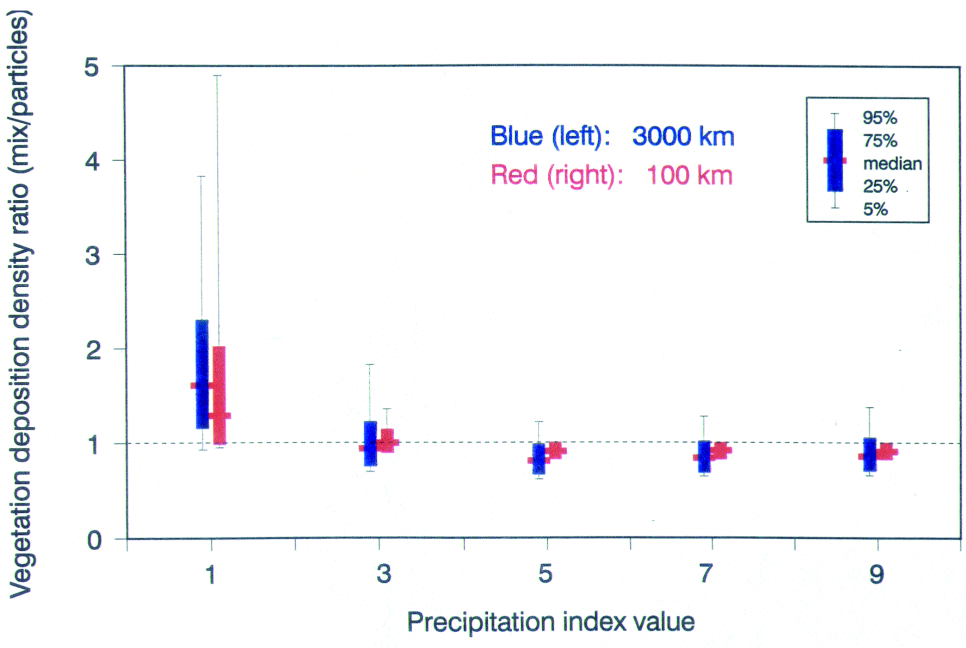
7.7. Variation of the vegetation deposition density as a function of the precipitation index value at the distance of 100 km from the NTS for ^{131}I attached to particles and distributed among 3 physico-chemical forms. Medians, as well as 50% and 95% confidence intervals, are shown on the vertical bars.



7.8. Variation of the vegetation deposition density as a function of the precipitation index value at the distance of 3000 km from the NTS for ^{131}I attached to particles and distributed among 3 physico-chemical forms. Medians, as well as 50% and 95% confidence intervals, are shown on the vertical bars.



7.9. Ratios of normalized vegetation deposition densities (mix/particles) as a function of the precipitation index value for downwind distances from the N of 100 and 3000 km. Medians, as well as 50% and 95% confidence intervals, are shown on the vertical bars.



CUSSION

lts of calculations taking into account the distribution of ·ding to several physico-chemical forms show that these ons do not produce vegetation deposition densities, efore, dose estimates that are substantially different from culated using the assumption that all ^{131}I was in particu-. The median values of the ratios of the ^{131}I vegetation n densities obtained when ^{131}I is distributed among var-sico-chemical forms and when ^{131}I is only in particulate within the range of 1.3 to 1.6 for dry deposition and e range of 0.8 to 1.0 in the presence of precipitation for of distances from the NTS. The assumption that is used port that ^{131}I is only associated with particles leads , on average, to an underestimation of the thyroid doses deposition of ^{131}I occurs in the absence of rain and to a erestimation of the thyroid doses when the deposition of s in the presence of rain. However, the uncertainty due sumption that ^{131}I is only associated with particles is s than the uncertainties related to the estimation of the n of ^{131}I per unit area of ground.

ne results shown in *Table A7.7* were used to assess the he assumption that all of the ^{131}I was associated with e material on dose estimates for locations relatively near and at greater distances. Distributions of daily rainfalls eriod 1951-1960 were extracted from the climatic or Las Vegas NV, Boise ID, Denver CO, Memphis TN, ille FL, and Albany NY[1]. The median ratios of $/A_p(P)]$ in *Table A7.7.* were used with the distributions of daily rainfall to estimate weighted biases for these particula tions. Some linear interpolations and extrapolations of the r in *Table A7.7.* were used to make the estimates because, exc for Denver, the distance from the NTS of the location consi differed from the distances for which $[A_p(mix)/A_p(P)]$ had b estimated.

Table A7.8. Median estimates of bias derived from precipitation frequencies during 1951-1960

Location	Distance from NTS (km)	Estimate of Bia
Las Vegas, NV	150	1.3
Boise, ID	720	1.3
Denver, CO	1020	1.1
Memphis, TN	2330	1.3
Jacksonville, Fl	3136	1.3
Albany, NY	3780	1.3

Table A7.7. Best estimates (medians) and ranges (5 and 95 percentiles) of vegetation deposition densities, A_p [(nCi m^{-2}) (nCi d m^{-3})$^{-1}$], for ^{131}I associated with particles, A_p (P), and for ^{131}I distributed according to the assumed mixture of physico-chemical forms, A_p (mix), for a range of daily rainfalls and distances from the NTS. The ratios, A_p (mix)/A_p (P), also are presented.

Reference daily rainfall	A_p(P)			A_p(mix)			A_p(mix)/A_p(P)		
	5%	Median	95%	5%	Median	95%	5%	Median	95%
X= 100 km									
0	54	240	1600	110	40	1600	0.95	1.29	4.90
0.15	250	560	1700	320	670	1800	0.94	1.10	2.02
0.5	590	1400	3100	670	1400	3000	0.91	1.00	1.36
1.5	3700	8400	19000	3500	7700	17000	0.86	0.93	0.99
5	8900	20000	45000	8200	18000	42000	0.85	0.91	0.97
15	6300	14000	22000	5800	13000	29000	0.85	0.92	0.98
50	7000	15000	33000	6400	14000	31000	0.85	0.92	0.98
100	7500	15000	31000	7000	13000	28000	0.85	0.91	0.98
150	7300	14000	29000	6800	13000	26000	0.85	0.91	0.98
X = 300 km									
0	170	410	1200	330	700	1700	0.95	1.51	4.22
0.15	630	200	2400	780	1400	2500	0.88	1.06	1.77
0.5	1200	2400	5000	1300	2400	4400	0.83	0.95	1.34
1.5	2700	5800	12000	2500	5100	10000	0.79	0.88	1.04
5	5600	13000	30000	4900	11000	24000	0.77	0.84	0.92
15	4200	9100	20000	3800	7700	17000	0.78	0.86	0.97
50	4400	9500	21000	4000	8200	17000	0.78	0.85	0.95
100	4900	9600	19000	4400	8200	15000	0.78	0.85	0.94
150	4800	9300	18000	4300	7900	15000	0.78	0.85	0.95
X = 1000 km									
0	460	760	1300	590	1000	2000	0.87	1.30	2.64
0.15	1200	1900	3300	1200	1900	3300	0.78	0.96	1.57
0.5	1600	2800	5500	1500	2600	4600	0.75	0.89	1.33
1.5	2300	4600	9500	2200	3900	7400	0.72	0.83	1.10
5	3800	8100	18000	3300	6400	13000	0.70	0.79	0.96
15	2900	6000	13000	2600	5000	9600	0.70	0.81	1.04
50	3300	6400	13000	2900	5200	10000	0.71	0.80	0.99
100	3500	6500	13000	3100	5300	9600	0.71	0.80	0.98
150	3400	5800	11000	2900	4800	8300	0.72	0.81	1.01
X = 3000 km									
0	530	690	9100	630	1100	2600	0.93	1.61	3.83
0.15	1000	1600	2700	1100	1800	3500	0.75	1.06	2.15
0.5	1300	2300	4400	1400	2300	4300	0.70	0.94	1.83
1.5	1800	3300	6400	1800	3000	5500	0.66	0.87	1.47
5	2700	5400	11000	2300	4400	8500	0.62	0.81	1.22
15	2100	3900	7900	2000	3400	6400	0.63	0.84	1.37
50	2300	4200	8900	2100	3600	6900	0.65	0.84	1.28
100	2400	4000	7400	2200	3500	6100	0.65	0.84	1.30
150	2000	3500	6400	1900	3100	5500	0.66	0.86	1.38

/as associated with particulate material may have
bias of 10-30% in the dose calculations. Bias estimates
of the six locations are shown in *Table A7.8;* the loca-
listed in order of increasing distance from the NTS.
estimates are generally uniform and do not show a
nce on the distance from the NTS.
ne estimates in the table reflect average precipitation fre-
during the 10-year period, not necessarily the condi-
ler which fallout deposition actually occurred. Detailed
n results for the important test series, tabulated in the
to the report, were used to estimate the mean bias dur-
ds when fallout occurred at four locations. These loca-
e chosen in part because of the relative completeness of
ds of gummed film deposition results. The estimates of
to the assumption that all the radioiodine was associat-
particles for the four locations are shown in *Table A7.9.*

.9. Mean estimates of bias derived from records of precipitation during actual fallout depositions from tests at the NTS.

Location	Estimated Mean Bias
Denver	1.3 ± 0.5
Memphis	1.1 ± 0.2
Detroit	1.3 ± 0.4
New York City	1.1 ± 0.2

ne mean estimate and an approximate standard devia-
given in the table. These more definitive results, based
ls of known fallout deposition, indicate that the likely
les of the bias are small. The uncertainties in the esti-
sufficiently large that one cannot conclude that there
s at these locations due to the assumption that all
ne was in particulate form.

duction was kindly performed for the project by Milton Smith (NOAA/Air
Laboratory).

Angeletti, L.; Sauve, A.M. Un modele pour l'evaluation de
vitesse de depot de l'iode vapeur sur l'herbe en fonction de
ments du climat. Rapport CEA-R-5213. Saclay, 1981.

Bunch, D. F. (ed.) Controlled Environmental Radiolodine T
at the National Reactor Testing Station. Progress Report
Number Three. Report ID0-12063; January 1968.

Cederwall, R.T.; Ricker, Y.E.; Cederwall, P. L.; Homan D. N
Anspaugh, L.R. Ground-based air-sampling measurements
the Nevada Test Site after atmospheric nuclear tests. Health
Phys. 59:533-540; 1990.

Coleman, L. F.; Postma, K. A. Washout of gaseous iodine
species. Precipitation scavenging (1970), pp. 271ú288. AE
symposium series 22. Report CONF-700601. December 1

Environmental Protection Agency. Final report of off-site
surveillance for the Baneberry event; December 18, 1970.
Western Environmental Research Laboratory report SWRH
107r; February 1972.

Gatz, D. F. Scavenging ratio measurements in METROMEX
Precipitation scavenging (1974), pp.71-87. ERDA Symposi
Series 41. Report CONF-741003; 1977.

Heinemann, K.; Vogt; K. J. Measurements of the deposition
iodine onto vegetation and of the biological half-life of iodi
vegetation. Health Phys.39:463-474(1980).

Hoffman, F. O. A reassessment of the deposition velocity in
prediction of the environmental transport of radiolodine fr
air to milk. Health Phys. 32:437-441; 1977.

Hoffman, F. 0.; Baes, C. F. III. A statistical analysis of se
parameters for predicting food chain transport and interna
of radionuclides. NUREG/CR-1004 and ORNL/NUREG/TM
282. Oak Ridge National Laboratory; 1979.

Hoffman, F.D.; Frank, M. L.; Blaylock, B. G.; von Bernuth,
Deming, E. J.; Graham, R. V.; MohrLacher, D. A.; Waters,
Pasture Grass Interception and Retention of ^{131}I, ^{7}Be, and
Insoluble Microspheres Deposited in Rain. Oak Ridge Nati
Laboratory report ORNL-6542, Environmental Sciences
Division, Oak Ridge, TN 37831; May 1989.

Krey, P. W.; Toonkel, L. E. Scavenging ratios. Precipitation
enging (1974), pp. 61-70. ERDA Symposium Series 41. Re
CONF-741003; 1977.

List, R. J. Radioactive debris from Operations Tumbler and
Snapper, observations beyond 320 miles from the test site,
II. Report NYO-4512 (Del.); 1953.

:a, Y.; Ohmomo, Y. Factors used for the estimation of
radioactive iodine intake through vegetation. I- Uptake
liodide by spinach leaves. Health Phys. 38: 307-314;

:a, Y.; Ohmomo, Y. Factors used for the estimation of
radioactive iodine intake through vegetation. II- Uptake
ıtal iodine by spinach leaves. Health Phys. 38: 315-
0b.

C. A.; Voilleque, P. G. The behavior of Cs-137 and
out radionuclides on a Michigan dairy farm. Health
: 777-792; 1971.

C. A.; Zimbrick, J. D. Kinetics of environmental
ne transport through the milk food chain. Chapter 31,
267 in: Environmental surveillance in the vicinity of
acilities. Proceedings of a symposium sponsored by the
ıysics Society; W.C.Reinig, B.M.E., C.H.P., ed. Charles
ıs; Springfield; 1970.

ı, R.C.; Koranda, J.J.; Wagner, W.L.; Phelps, P.; Lloyd,
spaugh, L.; Chapman, W. Radioecological studies in
sequent to the Baneberry event. Pages 150-169 in:
clides in Ecosystems. D.J. Nelson, ed.; 1971.

A. K. Effect of solubilities of gases on their scavenging
rops. Precipitation scavenging (1970), pp. 247-259.
ıposium Series 22. Report CONF-700601, Dec. 1970.

G. N. Parameterization for resuspension and for wet
deposition of particles and gases for use in radiation
ulations. Nuclear Safety 19(2):205-219; 1978.

J.; Heinemann, K.; Horbert, M.; Matthes, W.; Stoeppler,
suchung zur Ablagerung von Jod und Aerosolen.
sbericht, Zentralabteilung Strahienschutz,
:hungsanlage Julich; 1976.

:, P. G. Iodine species in reactor effluents and in the
ıent. Electric Power Research Institute report EPRI NP-
79.