



DEPARTMENT OF COMMUNITY SERVICES AND HEALTH

# Australian Radiation Laboratory



Inhalation Hazard Assessment at Maralinga and Emu

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Part 4

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Values for the various activity ratios are given in Table 5.2. These are time dependent to a greater or lesser extent depending on the half lives of the radionuclides concerned. For this reason, a date must be fixed at which to perform the dose calculations. The date which has been chosen in this case is mid 1987 as the aerial radiological survey which is the source of much of the primary data on  $^{241}\text{Am}$ ,  $^{137}\text{Cs}$  and  $^{60}\text{Co}$  activities was performed in May through July 1987 (EG&G, 1988).

By far the most significant nuclide in the inhalation dose assessment is  $^{239}\text{Pu}$ , and the major implication of choosing the above date is that the estimation of the contribution of  $^{239}\text{Pu}$  to doses is obtained directly from measured  $^{241}\text{Am}$  data via the appropriate  $^{239}\text{Pu}/^{241}\text{Am}$  activity ratios. Doses due to  $^{239}\text{Pu}$  and  $^{240}\text{Pu}$  will not change with the passage of tens of years due to the long half lives of the radionuclides (24,100 and 6,537 years respectively). Other implications are that current (mid 1990) doses from  $^{241}\text{Pu}$  (half life 14.4 years),  $^{137}\text{Cs}$  (30.2 years) and  $^{60}\text{Co}$  (5.3 years) will be a little smaller than those calculated for mid 1987. Doses from  $^{241}\text{Am}$  (half life 432.2 years) are presently increasing with the passage of time and will reach a maximum at approximately 2030 for Taranaki material.

Therefore, all calculated activity ratios in Table 5.2 are for mid 1987. Empirical  $^{239}\text{Pu}$  and  $^{240}\text{Pu}$  to  $^{241}\text{Am}$  activity ratios are for mid 1988 (Johnston et al. (1988)) or end 1988 (Burns et al. (1990)) but within experimental errors this one-year discrepancy is insignificant.

### $^{239}\text{Pu}$

Activity ratios of  $^{239}\text{Pu}$  to  $^{241}\text{Am}$  are given in Johnston et al. (1988) and Burns et al. (1990) for the major and minor trial sites of interest and for individual plumes at Taranaki. Experimental values for major trial sites only have been rounded off to one significant figure; in the context of the present assessment, this has no significant effect on the doses calculated or the conclusions. For central Taranaki, where the plutonium is an overlay of material from all 12 Vixen B trials, the  $^{239}\text{Pu}/^{241}\text{Am}$  activity ratio of 7.4 from Cooper et al. (1985) has been used, corrected to its mid 1987 value (7.0).

For the 12 Vixen B trials at Taranaki, detailed discussion of the contributions of individual shots to the different contamination plumes are

presented in Burns et al. (1990). For present purposes, we note that there were three Vixen B1 shots in September/October 1960, five Vixen B2 shots in April/May 1961, and four Vixen B3 shots in March/April 1963. Based on information provided by the U.K. Atomic Weapons Research Establishment (UKBDRSS, 1986) on plutonium/americium ratios for the various shots and on relevant meteorological data, the ARL measurements of activity ratios suggest the following compositions for the four major plumes.

The west plume results from a single shot (Vixen B3 shot 4) with an observed  $^{239}\text{Pu}/^{241}\text{Am}$  ratio of 8.0, and the north-west plume appears to result from several shots of the Vixen B2 and B3 series, all with similar ratios of ca. 6.8 (mean empirical value). The north-east plume appears to have resulted mainly from the trials Vixen B1 shot 2 and Vixen B2 shot 2. Empirical values for the  $^{239}\text{Pu}/^{241}\text{Am}$  ratio from Vixen B1 shot 2 are ca. 12 and from the second contributing shot are in the range 6.3 to 6.9. An average value of 9 is chosen for this plume in the present assessment.

The situation for the north plume is less clear. Meteorological data indicate that the remaining two shots which have  $^{239}\text{Pu}/^{241}\text{Am}$  ratios greater than 8, Vixen B1/1 (empirical ratio ca. 22) and B1/3 (empirical ratio 11.5), contribute to the north plume but the first of these in particular does not appear to be the source of the most intense northerly plume. Vixen B1/1 possibly constitutes a minor plume observed by the aerial survey (EG&G, 1988) that deviates west of the main plume. The main north plume is probably from Vixen B1/3, B2/1 and/or B3/3, the latter two shots having observed  $^{239}\text{Pu}/^{241}\text{Am}$  ratios between 6 and 8. Accordingly an average value of 8 is used for the north plume in the present assessment.

### $^{240}\text{Pu}$

Experimental values for  $^{240}\text{Pu}$  to  $^{241}\text{Am}$  ratios are given in Johnston et al. (1988) and Burns et al. (1990) for the minor trial sites of interest including individual plumes at Taranaki, and for the Tadge major trial site. Values for other major trial sites have been calculated directly from the (rounded)  $^{239}\text{Pu}/^{241}\text{Am}$  values assuming

- a)  $^{240}\text{Pu}$  constituted 3% by atoms of the total number of atoms of all plutonium,
- b) birthdates for the plutonium are the dates of the detonations, and
- c) the total number of atoms of all alpha-emitting actinide nuclides to atoms of the specific nuclide  $^{241}\text{Am}$  at the birthdate was 30000 to 1 (UKBDRSS, 1986).

Values of this ratio for the north and north-east plumes at Taranaki are averages of the appropriate observed values having regard to the probable composition of these plumes as discussed above.

### $^{241}\text{Pu}$

No empirical data on  $^{241}\text{Pu}$  activities are available. Instead,  $^{241}\text{Pu}/^{241}\text{Am}$  ratios have been calculated from the decay of  $^{241}\text{Pu}$  to  $^{241}\text{Am}$  by use of birthdate and decay parameters.

Specifically, for major trials, ratios have been calculated assuming birthdates for the plutonium are the dates of the detonations, and that the total number of atoms of all alpha emitting actinide nuclides to atoms of the specific nuclide  $^{241}\text{Am}$  at the birthdate was 30000 to 1 (UKBDRSS, 1986). For minor trials, the birthdates are assumed to be six months prior to the dates of the trials and there is assumed to be no  $^{241}\text{Am}$  present at the birthdates (chemical separation dates) of the plutonium. For the individual plumes at Taranaki, dates used are averages depending on the composition of the plumes as discussed above.

### $^{238}\text{Pu}$

Radiochemical analyses conducted for the TAG radioecology study (Giles et al., 1990) have yielded values of  $^{238}\text{Pu}$  activities for soil samples from the west and north-west plumes at Taranaki. These measurements indicate that the  $^{238}\text{Pu}/(^{239,240}\text{Pu})$  activity ratio is 0.020(1), where this value is the mean of 37 data points from Tables 17 and 18 with the standard deviation of the mean in parentheses. This value is adopted for all minor trial sites in the absence of further data. For major trial sites, a suitable value of 0.013(2) is available from radiochemical analyses on four high-volume air sampler filters from Tadge (Chapter 2).

### Uranium

For most of the minor trials involving uranium, it is believed that natural uranium, for which the isotopic ratios are well known, or depleted uranium was used. However, for the Vixen B trials some highly enriched uranium was used in conjunction with experiments involving plutonium. Measurements from Johnston et al. (1988) and Burns et al. (1990) indicate the

magnitude of the  $^{235}\text{U}/^{241}\text{Am}$  activity ratios, which appear reasonably consistent for given areas. Values of this ratio used in the dose assessments are 0.0001 for inner Taranaki and the NE plume, 0.0002 for the W and NW plumes, and 0.0003 for the N plume. Other uranium isotopes are ignored at Taranaki. Also the uranium used in Vixen B calibration rounds is not considered.

### $^{90}\text{Sr}$

In the fallout areas,  $^{90}\text{Sr}$  may be an important radionuclide. The activity ratio of  $^{90}\text{Sr}/^{137}\text{Cs}$  is given for five ground zeros at Maralinga in Cooper et al. (1978). Values are 0.24 for One Tree, 1.03 for Marcoo, 0.48 for Breakaway, 0.61 for Tadge and 0.26 for Biak. The mean value, 0.52, is used for the Taranaki NE plume where the fallout clearly arises from a number of major trials. For Emu suitable values of 0.18 within 100 m of ground zeros and 0.10 beyond 100 m are reported in MacLagan et al. (1979).

### $^{241}\text{Am}$

Also in the fallout areas, actinides are likely to be important and hence ratios of  $^{241}\text{Am}/^{137}\text{Cs}$  have been estimated from more contaminated areas so that estimates of the impact of actinides can be made near the limit of  $^{137}\text{Cs}$  detection (and below the limit of  $^{241}\text{Am}$  detection) of the aerial radiological survey. For a range of soil samples from Totem I, II and One Tree (Cooper et al., 1978), average values for this ratio (corrected to mid 1987) are 0.2, 0.4 and 0.2 respectively. From data in Duggleby et al. (1985), ratios for other individual major trials are 0.3 for Breakaway, 0.5 for Biak and 2.2 for Tadge.

### 5.3.8 Depth Distribution

In order to convert from activity per unit surface area to activity per unit mass it is necessary to know the profile of activity with depth, as well as soil density. Data are given in Chapter 4 for depth profiling which show that in undisturbed areas most of the activity is in the top 10 mm of most samples and that at least 85% is in the top 20 mm. Measurements of soil density range from 1.65 to 1.78 g/cm<sup>3</sup>. From these data and for the purposes of calculation it is assumed that, in undisturbed areas, all the activity is in the top 10 mm of soil and that it is uniformly mixed throughout that depth. Soil density is taken to be 1.7 g/cm<sup>3</sup>. From these assumptions the

airborne dust concentration of  $1 \text{ mg/m}^3$  corresponds to a resuspension factor<sup>2</sup> of  $6 \times 10^{-8}$  per m for an enhancement factor of unity.

In the case of  $^{241}\text{Am}$  which emits a gamma ray of sufficiently low energy to be significantly attenuated by thin layers of soil, measurements of activity per unit area from the aerial survey (EG&G, 1988) must be multiplied by a factor depending on the known or assumed depth distribution. If it is assumed that all the americium (and plutonium) is uniformly mixed in the top 10 mm of soil, the appropriate factor is 1.33. For more energetic nuclides such as  $^{137}\text{Cs}$  and  $^{60}\text{Co}$ , the appropriate factor is essentially unity.

Thus to convert from  $^{241}\text{Am}$  activity per unit surface area (aerial survey data in  $\text{kBq/m}^2$ ) to activity per unit mass (units of  $\text{Bq/g}$ ) in the top 10 mm, the appropriate factor is  $1.33/17$ , recognising that a square metre to a depth of 10 mm contains 17 kg of soil.

It is important to note that the 'enhancement factor' as defined and determined in Chapters 3 and 4 contains no depth-related information. It merely relates the activity concentration in the respirable fraction of a given soil sample to the activity concentration of the bulk sample, whether the sample is of surface soil or a suspension in air.

In examining the effect of the depth distribution of contamination on dose assessment, two factors require consideration. These are the correction necessary to aerial survey surface concentration data to allow for attenuation by blanketing soil of the gamma-ray intensity from radionuclides beneath the surface, and the depth of soil which is resuspended which affects airborne contamination concentrations. We will restrict the following discussion to the case of  $^{241}\text{Am}$  for which the attenuation correction is significant.

Two cases will be considered, those of uniform distribution of contamination to a given depth, and of non-uniform distribution. For uniform distribution, the factor of 1.33 corrects aerial survey  $^{241}\text{Am}$  concentration data for a uniform distribution to 10 mm. If the depth of soil resuspended in a dust-raising activity is 10 mm or less, the initial airborne activity concentration will be essentially that determined for the soil, as assumed in

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<sup>2</sup> Resuspension factor relates airborne activity concentration to activity surface density and has dimensions of inverse length.

the present assessments. However, if more than 10 mm is resuspended, i.e. contaminated and uncontaminated soil is being mixed in the dust-raising activity, the activity concentration in air will be less than that in the top 10 mm of soil. In this instance the present dose assessments will be overestimates.

If the contamination were uniformly mixed to a depth less than 10 mm, say in the unlikely event that all is on the surface in the top 1 mm, the appropriate factor to convert aerial survey data is closer to unity than 1.33. However, the quantity of soil is then 10 times less (1.7 kg) so that if resuspension occurs only from the top 1 mm, airborne concentrations would be higher than those assumed in the present dose assessment by a factor of approximately 10/1.33. For this situation, but with the dust-raising activity again suspending all of the top 10 mm of soil, airborne concentrations decrease 10-fold bringing them close to those assumed in the present assessments (actually, less by a factor of ca. 1/1.33).

If the contamination is uniformly mixed to a depth greater than 10 mm, as in the treated ('ploughed') areas, the factor to correct for attenuation of the aerial survey data becomes greater but the volume of soil increases from the 17 kg in the top 10 mm, and the two effects largely compensate. The best solution in this circumstance is to use measured soil activity concentration data rather than aerial survey data.

Turning to the second case for consideration, viz. that of non-uniform distribution of activity with depth, for purposes of illustration we<sup>r</sup> will consider the (not unlikely) situation of an exponential profile. As before, the correction ( $f_{\text{EGG}}$ ) to be applied to the aerial survey data depends on the depth (strictly, relaxation length  $D$ ) of the distribution, with values  $f_{\text{EGG}}$  of 1.0, 1.3, 1.6, and 2.2 for  $D$  of zero, 5, 10, and 20 mm (EG&G, 1988). Assuming that the top 10 mm is resuspended (certain dust-raising activities will obviously raise more or less than this, such as natural resuspension which will only raise the very top layer), the fraction  $f_{\text{ACT}}$  of activity down to depth 10 mm is 0.865, 0.632, and 0.393 for  $D$  of 5, 10, and 20 mm. The combined correction factor converting aerial survey data to activity in the top 10 mm available for resuspension is  $f^* = f_{\text{EGG}} \times f_{\text{ACT}}$ , with values 1.124, 1.011, and 0.865 for relaxation lengths  $D$  of 5, 10, and 20 mm respectively.

Thus for unploughed areas values of  $D$  of 5 mm (which implies 86.5% of activity in the top 10 mm) and an  $f^*$  of 1.124 seem appropriate having regard

to the depth profile data in Chapter 4. In ploughed areas, by extrapolation to a D value of 30 mm (which implies 86.5% of activity is in the top 60 mm), the appropriate correction factor is an  $f^*$  value of 0.76.

To conclude, correction factors to convert aerial survey  $^{241}\text{Am}$  data to activities per unit mass vary with assumptions about the depth distribution of the contamination in the soil and the depth of soil suspended in any given activity, but cluster reasonably close to unity due to the compensatory nature of the effects. The value of 1.33 used in the present dose assessment is probably a satisfactorily conservative compromise.

#### 5.3.9 Breathing Rates

Breathing rates for adults, children and infants are taken from Haywood (1987). These rates are 8400  $\text{m}^3/\text{year}$  for adults, 5500  $\text{m}^3/\text{year}$  for children and 1400  $\text{m}^3/\text{year}$  for infants. These data are for the British population. Data for Pitjantjatjara people are unavailable but are unlikely to differ substantially.

### 5.4 RESULTS AND DISCUSSION

Committed Effective Dose Equivalent values for long-term inhabitants in the contaminated areas are presented in Table 5.3. A more complete breakdown of the radionuclides that contribute to these CEDE is presented in Appendix 5.1. For all sites except Kuli, the CEDE is dominated by  $^{239}\text{Pu}$  with minor contributions from other actinides. At Kuli, the area is contaminated with uranium and plutonium is not present.

None of the fission or activation products remaining at Maralinga and Emu is a significant hazard for the inhalation pathway.

Table 5.3 Estimated Committed Effective Doses from Inhalation  
for Full-Time Aboriginal Residents  
in Contaminated Areas at Maralinga and Emu

Site	mSv/year		
	Adults	Children	Infants
Central Taranaki	273.0	306.2	124.5
W plume - $^{241}\text{Am}$ A contour	3.4	3.8	1.5
NW plume - $^{241}\text{Am}$ A contour	2.9	3.3	1.3
N plume - $^{241}\text{Am}$ A contour	3.3	3.7	1.5
NE plume - $^{241}\text{Am}$ A contour	3.7	4.2	1.7
Wewak - VK60A,60C central 0.02 km <sup>2</sup>	105.1	118.0	48.2
Wewak - VK60A,60C $^{241}\text{Am}$ A contour	3.5	3.9	1.6
Wewak - VK33 $^{241}\text{Am}$ B contour	29.3	32.9	13.4
TM100 - $^{241}\text{Am}$ C contour (0.1 km <sup>2</sup> )	35.8	40.2	16.4
TM100 - $^{241}\text{Am}$ A contour	3.6	4.0	1.6
TM101 - $^{241}\text{Am}$ C contour (0.04 km <sup>2</sup> )	15.5	17.4	7.1
TM101 - $^{241}\text{Am}$ A contour	1.5	1.7	0.7
Kuli - $^{238}\text{U}$ D contour (0.02 km <sup>2</sup> )	11.2	16.9	11.2
Kuli - $^{238}\text{U}$ A contour	1.3	1.9	1.3
Ground Zero Totem I	4.0	5.2	2.4
Ground Zero Totem II	16.4	21.4	9.9
Ground Zero Breakaway	1.2	1.6	0.7
Ground Zero Biak	5.6	7.2	3.3
Ground Zero Tadge	42.0	54.6	25.3
Ground Zero One Tree	2.6	3.4	1.6
Totem I $^{137}\text{Cs}$ A contour	0.2	0.2	0.1
Totem I $^{241}\text{Am}$ A contour	4.1	5.4	2.5
Totem II $^{137}\text{Cs}$ A contour	0.5	0.6	0.3
Totem II $^{241}\text{Am}$ A contour	5.1	6.7	3.1
Maralinga fallout - $^{137}\text{Cs}$ A contour	0.1	0.1	0.0
Fallout field 2nd Av. & Right St.	5.6	7.3	3.4
Pu contaminated area NNE of Tadge	14.4	18.8	8.7

### 5.4.1 Casual Visitors

A casual visitor to these areas is unlikely to remain in contaminated areas for more than 1/50 of the year and probably would be exposed to lower dust concentrations than a member of an Aboriginal community. It is assumed here that the visitor does not engage in dust raising activities and consequently is only exposed to ambient sources of resuspended dust. The greatest hazard to a casual visitor would arise if he were present during a dust storm (and unable to shelter in a vehicle or move out of the area while conditions were unpleasant). Casual visits by adults to two of the most hazardous sites are considered, viz. central Taranaki and the Tadge ground zero area. Table 5.4 lists computed hourly doses for casual visits during calm conditions, during dust storms, and for mean conditions over the period May 1987 to March 1988 by use of activity concentration data from Table 2.5, Chapter 2. It is assumed that all of the observed activity is in the respirable size range.

Table 5.4  $^{241}\text{Am}$  Activity Concentrations and Hourly Doses ( $\mu\text{Sv/h}$ )  
for Casual Visitors

Site	Calm Conditions		Dusty Conditions*		Mean Conditions	
	$\mu\text{Bq/m}^3$	Dose	$\mu\text{Bq/m}^3$	Dose	$\mu\text{Bq/m}^3$	Dose
Central Taranaki	9	0.005	800	0.42	150	0.078
Tadge G.Z.	4	0.006	470	0.73	21	0.033

\* The peak activity concentrations were measured over an 84.6 hour sampling period at Taranaki and a 49.7 hour period at Tadge (Appendix 2.2, Chapter 2).

These data indicate that there is no inhalation hazard for casual visitors to even the most contaminated sites at Maralinga and Emu, so long as dust-raising activities are avoided. As each of the measurements under dusty conditions included one severe dust storm of several hours duration, these measurements are best interpreted as doses of 36  $\mu\text{Sv}$ /dust storm in both cases. This implies that a casual visitor would need to be present throughout 28 such dust storms to reach a total CEDE of 1 mSv.

### 5.4.2 Australian Protective Service Patrols

Patrols of the forward area of Maralinga are usually performed by personnel of the Australian Protective Service (APS) on a daily basis. Vehicles are air-conditioned and would normally be driven with windows closed. Recently APS personnel have been advised to avoid dirt tracks in contaminated areas, as a precaution against the dust hazard as well as to avoid the possibility of having to change punctured tyres in these areas.

To gain some feel for the potential inhalation hazard experienced by APS personnel during these routine patrols, we have estimated a dose based on the following assumptions. We have assumed a daily patrol involving 15 minutes driving on dirt tracks at central Taranaki (say around the perimeter fence), 15 minutes on dirt tracks at major trial sites (using Tadge parameters), 15 minutes on dirt tracks at the central Wewak area, and 15 minutes on dirt tracks at the TM sites (using TM100 parameters). The dose is calculated for a six-week period (the normal APS tour of duty at Maralinga) and, in the absence of any data on applicable dust loadings, is given per  $\text{mg}/\text{m}^3$ . The computed dose due to inhalation is 0.55 mSv.

Obviously if dirt tracks in contaminated areas are avoided as much as possible, the dose will be significantly smaller than that calculated above. For a single vehicle driven on dirt tracks with windows closed, the respirable dust loading will be substantially lower than  $1 \text{ mg}/\text{m}^3$ , and the inhalation dose will be proportionately lower. The worst case as far as the inhalation hazard is concerned would occur in the situation of two vehicles following one another on dirt tracks, with windows in the second vehicle open. The only data which have some bearing on this situation are given in Appendix 3.4 of Chapter 3 where respirable ( $<7 \mu\text{m}$ ) dust loadings of 0.8 and  $13.3 \text{ mg}/\text{m}^3$  were measured for the open tray section of a utility vehicle being driven along a dirt track, singly and following a second vehicle respectively.

Having regard to current APS practices, the estimated CEDE of 0.55 mSv per six week period per  $\text{mg}/\text{m}^3$  of respirable dust would appear to indicate a comfortable safety margin for the inhalation hazard, especially considering that actual dust loadings will certainly be much lower than  $1 \text{ mg}/\text{m}^3$ . It would seem prudent, however, to ensure that APS personnel at Maralinga are thoroughly aware of the nature of the potential inhalation hazard and of the simple steps which can be taken to minimise very substantially any risk.

#### 5.4.3 Aboriginal Health and Lifestyle

There are several lifestyle aspects and related health issues which might considerably alter doses received by residents of an Aboriginal community living in contaminated areas. It is noted that the Aborigines at Oak Valley are commonly mouth-breathers, many are heavy smokers, and upper respiratory tract infections are endemic (Palmer & Brady, 1988).

Mouth-breathers tend to have lower deposition in the N-P region of the respiratory tract. Wise (1985) has examined DPUI variability using regional deposition data from human experiments by Chan and Lippmann (1980) and Yu et al. (1981). By use of this method for  $^{239}\text{Pu}$  there is a factor of two increase in DPUI for Class Y for mouth-breathers while there is a small decrease for Class W. Smoking further complicates the matter, but generally seems to have a small effect on regional deposition while substantially altering mechanical clearance capability. Endemic respiratory tract infections also complicate the situation, probably causing changes in regional deposition and clearance capability. These infections may also be related to high dust concentrations to which the Aborigines are exposed and possibly are a reason why they are mouth-breathers.

Other factors which may effect DPUI are the general health and dietary deficiencies of the population. The dose conversion factors used in this assessment have been computed from a model designed for essentially healthy workers. The people living at Oak Valley do not generally fit this description. Unfortunately, while these factors are obviously important in assessing doses that might be received by an Aboriginal resident in a contaminated area little or no data exist to quantify their importance. Assessing these factors probably requires a further specialised study.

#### 5.4.4 Sources of Uncertainty

The dose estimates presented are dependent on many factors some of which are not well known. All of the estimated doses depend linearly on breathing rates, activity data, dust concentration and DPUI data. Breathing rates given on page 132 are reasonably well known.

Activity on the ground is fairly well known, but activity in the air is not well known. In many cases enhancement factors have been assumed based on

only a few experimental determinations. These must be considered quite uncertain with both higher and lower values being possible.

Dust concentration is uncertain because of a lack of experimental data, but the assumed values are believed to be conservative. The results indicate that doses to children are higher than doses to adults and infants. This is a consequence of children being subjected to higher dust concentrations than adults because of their play activities and because of generally higher dose per unit intakes than adults, which more than offset their smaller breathing rates. Thus children form the critical group.

All DPUI values have considerable inherent uncertainty, and further uncertainty because of the unknown impact of Aboriginal health and lifestyle issues discussed above. The use of 5  $\mu\text{m}$  AMAD may also be inappropriate at sites not sampled. However, uncertainty in this parameter is unlikely to cause much error.

#### 5.4.5 Uncertainty Analysis

In order to develop some understanding of the range of uncertainty in the estimated doses, a particular case - the committed effective dose equivalent for  $^{239}\text{Pu}$  inhaled by a 10 year old child living for one year at a level of 1.4  $\text{kBq/m}^2$  of  $^{241}\text{Am}$  (A contour) along the north plume - was treated in more detail. Each of the four parameters dust loading,  $^{239}\text{Pu}/^{241}\text{Am}$  ratio, enhancement factor for resuspended respirable dust, and breathing rate, was assigned a distribution function with a specified median and range (10th and 90th percentiles). The assigned values and distribution functions are presented in Table 5.5. These values are close to those suggested by the TAG, and are chosen to keep the distribution functions simple.

A Monte Carlo approach was then used to draw values for the first four parameters in Table 5.5 and the calculation of dose was repeated 10,000 times. The distribution of answers is illustrated in Figure 5.1. The median value for  $^{239}\text{Pu}$  only is 2.9 mSv, with 10th and 90th percentile values of 1.0 and 8.4 mSv respectively. Contributions from the other actinide nuclides are expected to behave in the same way.

Thus without taking into account the range of uncertainties in the ICRP-based dose per unit intake factors (the other fixed parameters will have a lesser effect) the assessed doses in Table 5.3 are likely to be within a factor of three (10th and 90th percentiles) of the best estimates of dose.

Table 5.5 Parameters for use in Uncertainty Analysis

Parameter	10th Percentile	Median	90th Percentile	Range*	Distribution
Dust loading (mg/m <sup>3</sup> )	0.6	1.5	3.7	2.5	log normal
<sup>239</sup> Pu/ <sup>241</sup> Am ratio	6.7	8	9.6	1.2	log normal
Enhancement factor	3.8	6	9.6	1.6	log normal
Breathing rate	3500	5500	7500	2000†	normal
Depth factor		1.33			fixed value
DPUI (Sv/Bq)		6.6E-5			fixed value
<sup>241</sup> Am level (kBq/m <sup>2</sup> )		1.4			fixed value

\* 1.28 × geometric standard deviation (gsd) for log normal distribution

† 1.28 × standard deviation for normal distribution

If a range of uncertainty (gsd) of a factor of three is included in the estimate of dose factors (NRPB private communication, 1990) the median value for the same case is unchanged, but with 10th and 90th percentiles becoming 0.6 and 12.8 mSv respectively. Thus, under these assumptions, there is one chance in ten that the true dose is less than 0.6 mSv and one chance in ten that it is greater than 13 mSv - that is, a factor of ca. 4.6 either side of the median.

#### 5.4.6 Occupancy Factors

The doses computed above are for permanent residence at one site for the inhalation exposure pathway only. It is not appropriate to apply occupancy factors until doses from all pathways are combined. However, a few observations on occupancy factors may aid the debate on what occupancy factors are appropriate for the current problem.

Palmer and Brady (1988) indicate that the Oak Valley people move camp every 7 to 10 days after the resources of the area around the camp are depleted. They then tend to move along roads to a new site usually one or two kilometres distant where they establish a new camp next to the road.

It is tempting to simply compute:-

$$\text{average dose} = \frac{\int \text{dose}(r) \, dr}{\int dr}$$

where  $\text{dose}(r)$  is the CEDE at  $r$  and  $r$  is an element of the set of all positions along roads available to the Aborigines for camping.

Clearly an area available for unrestricted use by the Aboriginal people should not be so contaminated that they would receive a CEDE of 1 mSv at that site. Contaminated areas tend to intersect roads for many kilometres and so people may camp in several consecutive contaminated locations or may find some areas attractive and others taboo because of cultural or other reasons. Thus it appears such a simplistic approach to occupation factor may not be very helpful. Nevertheless, past experience indicates that the Oak Valley community is fairly mobile and it is unlikely that total occupancy of contaminated areas would exceed ten percent.

In practice it may be necessary to monitor the movements of Aboriginal people who have unrestricted access to an area where they may receive a dose in excess of 1 mSv/year.

## 5.5 CONCLUSIONS

Committed Effective Dose Equivalents have been computed for a range of sites at Maralinga and Emu for the inhalation pathway. Other pathways are handled elsewhere (Haywood and Smith, 1990) but it is clear that inhalation is by far the dominant contributor to overall dose.

With the exception of Kuli which is contaminated with uranium, at all other sites it is only the inhalation of plutonium and americium that contributes significantly to the dose, and of these  $^{239}\text{Pu}$  is the largest contributor. Therefore, having regard to the long half lives of the radionuclides concerned, the inhalation problems highlighted by this dose assessment will not diminish significantly within any reasonable period of time and hence management strategies must be developed to deal with such problems.

While many of the input parameters in the dose calculations are subject to considerable uncertainty, and attempts have been made to gain some feel for the effects of these uncertainties, one of the most uncertain is the occupancy factor. As it is impossible to predict with confidence occupancy factors for the Maralinga and Emu areas by future Aboriginal communities, a value of 100% has been assumed in the calculations reported above. In practice all doses reported above must be scaled down by whatever is assumed to be a reasonable occupancy factor for the contaminated sites and plumes. Having regard to current Aboriginal practices, we would suggest that realistic occupancy factors would be closer to 10% than the assumed 100%.

From the dose estimates given in Table 5.3, certain areas have inhalation dose rates that are too high to be acceptable under all but the most rigorously controlled circumstances. These include central areas at Taranaki, Wewak, TM100, TM101, Kuli, Totem II and Tadge. At the other extreme, while plutonium is detectable on the ground way beyond the limit of detection ( $^{241}\text{Am}$  A contour) of the aerial survey (Johnston et al., 1989), for any realistic occupancy factor the corresponding inhalation dose is much less than 1 mSv per year. For example, the highest value for  $^{241}\text{Am}$  observed for the north-west plume crossing Oak Valley Road was  $0.2 \text{ kBq/m}^2$  (Johnston et al., 1989) giving an estimated dose of 0.5 mSv/y for children assuming 100% occupancy.

In between these extremes, the above considerations suggest that the  $^{241}\text{Am}$  A contour of the aerial survey, which roughly coincides with the boundary of the present controlled area of Maralinga (Section 400), is a reasonable delineator beyond which dose rates for the inhalation of actinides do not constitute a radiological hazard, using reasonable assumptions about occupancy factors.

The obvious implication of some of the higher dose estimates in Table 5.3 is that extreme care must be taken in any rehabilitation processes, which themselves may raise high levels of dust, to ensure that work crews are provided with necessary protection. Such workers may have to be classified as designated radiation workers, properly monitored, and subject to NHMRC recommended limits for radiation workers.

Properly informed casual visitors making intermittent forays to the area, for example tourists, geological prospectors and surveyors, who do not engage in dust raising or soil disturbance activities are very unlikely to receive a CEDE by inhalation of 1 mSv.

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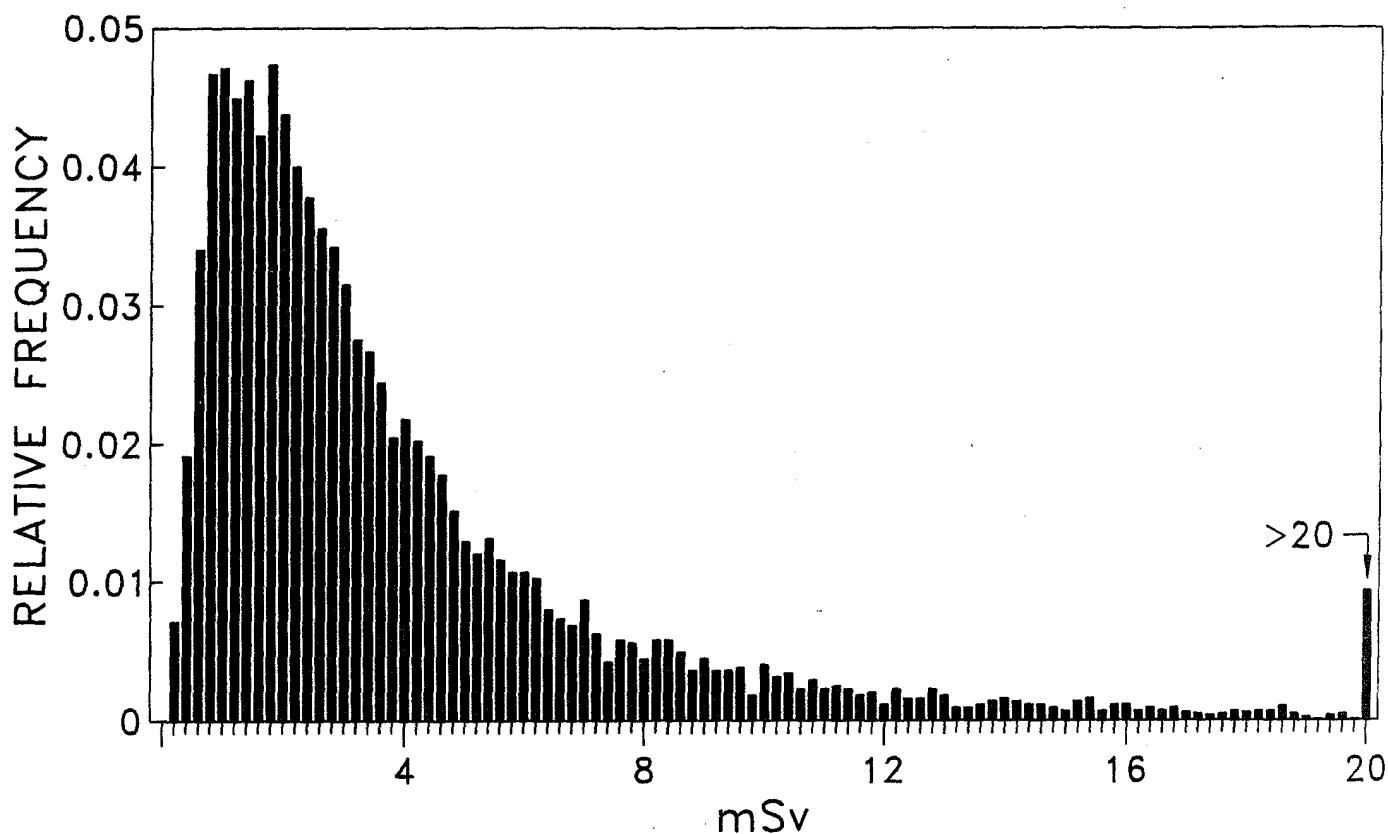


Fig. 5.1 Distribution of dose assessments calculated by a Monte Carlo method for inhalation of  $^{239}\text{Pu}$  by a 10 year old child living for one year at a level of  $1.4 \text{ kBq/m}^2$  of  $^{241}\text{Am}$  (A contour) in the north plume of contamination at Taranaki. This analysis is based on uncertainties in the parameters, expressed as statistical distributions (Table 5.5), but does not include uncertainty in the ICRP-based dose per unit intake factor. The central estimate is 2.9 mSv/year.

**APPENDIX 5.1****Details of Dose Calculations**

The calculations of Committed Effective Dose Equivalent for Aboriginal residents of the following contaminated areas were performed using a spreadsheet program based on the assumptions outlined in Section 5.3 above.

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Taranaki - central area ca. 10 hectares KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	7 ARL/TR70		
Pu-240/Am-241	1 ARL/TR86		
Pu-241/Am-241	12.2		
U-234/U-238	N/A	Depth factor	1
U-235/Am-241	0.0001 ARL/TR86	Enhancement factor	20

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	3.0E+00 ARL/TR70	
Pu-238	4.8E-01	
Pu-239	2.1E+01	
Pu-240	3.0E+00	
Pu-241	3.7E+01	
U-234	0.0E+00	
U-235	3.0E-04	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	28.3	10%	31.9	10%	13.0	10%
Pu-238	4.4	2%	5.0	2%	2.1	2%
Pu-239	204.6	75%	229.6	75%	93.9	75%
Pu-240	29.2	11%	32.8	11%	13.4	11%
Pu-241	6.5	2%	6.9	2%	2.1	2%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	273.0		306.2		124.5	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Taranaki - W plume, Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	8 ARL/TR86		
Pu-240/Am-241	1.2 ARL/TR86		
Pu-241/Am-241	13.4		
U-234/U-238	N/A	Depth factor	1.33
U-235/Am-241	0.0002 ARL/TR86	Enhancement factor	6

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	1.1E-01	1.4E+00 EG&G
Pu-238	2.0E-02	
Pu-239	8.8E-01	
Pu-240	1.3E-01	
Pu-241	1.5E+00	
U-234	0.0E+00	
U-235	2.2E-05	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
	Dose (mSv/y)	%	Dose (mSv/y)	%	Dose (mSv/y)	%
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.3	9%	0.3	9%	0.1	9%
Pu-238	0.1	2%	0.1	2%	0.0	2%
Pu-239	2.6	76%	2.9	76%	1.2	76%
Pu-240	0.4	11%	0.4	11%	0.2	11%
Pu-241	0.1	2%	0.1	2%	0.0	2%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	3.4		3.8		1.5	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Taranaki - NW plume, Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	6.8 ARL/TR86		
Pu-240/Am-241	1 ARL/TR86		
Pu-241/Am-241	12.6		
U-234/U-238	N/A	Depth factor	1.33
U-235/Am-241	0.0002 ARL/TR86	Enhancement factor	6

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	1.1E-01	1.4E+00 EG&G
Pu-238	1.7E-02	
Pu-239	7.4E-01	
Pu-240	1.1E-01	
Pu-241	1.4E+00	
U-234	0.0E+00	
U-235	2.2E-05	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.3	11%	0.3	11%	0.1	11%
Pu-238	0.0	2%	0.1	2%	0.0	2%
Pu-239	2.2	74%	2.4	74%	1.0	75%
Pu-240	0.3	11%	0.4	11%	0.1	11%
Pu-241	0.1	3%	0.1	2%	0.0	2%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	2.9		3.3		1.3	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Taranaki - N plume, Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	8 ARL/TR86		
Pu-240/Am-241	1 ARL/TR86		
Pu-241/Am-241	12.2		
U-234/U-238	N/A	Depth factor	1.33
U-235/Am-241	0.0003 ARL/TR86	Enhancement factor	6

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	1.1E-01	1.4E+00 EG&G
Pu-238	2.0E-02	
Pu-239	8.8E-01	
Pu-240	1.1E-01	
Pu-241	1.3E+00	
U-234	0.0E+00	
U-235	3.3E-05	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.3	9%	0.3	9%	0.1	9%
Pu-238	0.1	2%	0.1	2%	0.0	2%
Pu-239	2.6	77%	2.9	77%	1.2	78%
Pu-240	0.3	10%	0.4	10%	0.1	10%
Pu-241	0.1	2%	0.1	2%	0.0	2%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	3.3		3.7		1.5	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Taranaki - NE plume, Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	0.52 ARL/TR5 (av.)		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	9 ARL/TR86		
Pu-240/Am-241	1.2 ARL/TR86		
Pu-241/Am-241	11.6		
U-234/U-238	N/A	Depth factor	1.33
U-235/Am-241	0.0001 ARL/TR86	Enhancement factor	6

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m <sup>2</sup>
Sr-90	1.5E-02	
Cs-137	2.9E-02	5.0E-01 EG&G
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	1.1E-01	1.4E+00 EG&G
Pu-238	2.2E-02	
Pu-239	9.9E-01	
Pu-240	1.3E-01	
Pu-241	1.3E+00	
U-234	0.0E+00	
U-235	1.1E-05	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.3	8%	0.3	8%	0.1	8%
Pu-238	0.1	2%	0.1	2%	0.0	2%
Pu-239	2.9	78%	3.2	78%	1.3	78%
Pu-240	0.4	10%	0.4	10%	0.2	10%
Pu-241	0.1	2%	0.1	2%	0.0	1%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	3.7		4.2		1.7	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Wewak - VK60A,60C (0.02 sq.km central area) KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	20 ARL/TR80		
Pu-240/Am-241	1.4 ARL/TR80		
Pu-241/Am-241	11.8		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	4

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	2.3E+00	3.0E+01 EG&G
Pu-238	1.0E+00	
Pu-239	4.7E+01	
Pu-240	3.3E+00	
Pu-241	2.8E+01	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	4.4	4%	5.0	4%	2.0	4%
Pu-238	1.8	2%	2.1	2%	0.9	2%
Pu-239	91.5	87%	102.6	87%	42.0	87%
Pu-240	6.4	6%	7.2	6%	2.9	6%
Pu-241	1.0	1%	1.0	1%	0.3	1%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	105.1		118.0		48.2	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Wewak - VK60A,60C, Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	20 ARL/TR80		
Pu-240/Am-241	1.4 ARL/TR80		
Pu-241/Am-241	11.8		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	4

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	7.8E-02	1.0E+00 EG&G
Pu-238	3.3E-02	
Pu-239	1.6E+00	
Pu-240	1.1E-01	
Pu-241	9.2E-01	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	4%	0.2	4%	0.1	4%
Pu-238	0.1	2%	0.1	2%	0.0	2%
Pu-239	3.0	87%	3.4	87%	1.4	87%
Pu-240	0.2	6%	0.2	6%	0.1	6%
Pu-241	0.0	1%	0.0	1%	0.0	1%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	3.5		3.9		1.6	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Wewak - VK33, Am-241 B contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class. of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	23 ARL/TR80		
Pu-240/Am-241	1 ARL/TR80		
Pu-241/Am-241	10.6		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	10

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	2.3E-01	3.0E+00 EG&G
Pu-238	1.1E-01	
Pu-239	5.4E+00	
Pu-240	2.3E-01	
Pu-241	2.5E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	1.1	4%	1.2	4%	0.5	4%
Pu-238	0.5	2%	0.6	2%	0.2	2%
Pu-239	26.3	90%	29.5	90%	12.1	90%
Pu-240	1.1	4%	1.3	4%	0.5	4%
Pu-241	0.2	1%	0.2	1%	0.1	1%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	29.3		32.9		13.4	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: TM100 - Am-241 C contour (ca. 0.1 sq.km) KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	20 ARL/TR80		
Pu-240/Am-241	1.9 ARL/TR80		
Pu-241/Am-241	11.5		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	4

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	7.8E-01	1.0E+01 EG&G
Pu-238	3.4E-01	
Pu-239	1.6E+01	
Pu-240	1.5E+00	
Pu-241	9.0E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	1.5	4%	1.7	4%	0.7	4%
Pu-238	0.6	2%	0.7	2%	0.3	2%
Pu-239	30.5	85%	34.2	85%	14.0	85%
Pu-240	2.9	8%	3.2	8%	1.3	8%
Pu-241	0.3	1%	0.3	1%	0.1	1%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	35.8		40.2		16.4	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: TM100 - Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	20 ARL/TR80		
Pu-240/Am-241	1.9 ARL/TR80		
Pu-241/Am-241	11.5		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	4

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	7.8E-02	1.0E+00 EG&G
Pu-238	3.4E-02	
Pu-239	1.6E+00	
Pu-240	1.5E-01	
Pu-241	9.0E-01	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
	Dose (mSv/y)	Committed Effective Dose (mSv)	Dose (mSv/y)	Committed Effective Dose (mSv)	Dose (mSv/y)	Committed Effective Dose (mSv)
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	4%	0.2	4%	0.1	4%
Pu-238	0.1	2%	0.1	2%	0.0	2%
Pu-239	3.0	85%	3.4	85%	1.4	85%
Pu-240	0.3	8%	0.3	8%	0.1	8%
Pu-241	0.0	1%	0.0	1%	0.0	1%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	3.6		4.0		1.6	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: TM101 - Am-241 C contour (ca. 0.04 sq.km) KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	7.6 ARL/TR80		
Pu-240/Am-241	1.2 ARL/TR80		
Pu-241/Am-241	12.1		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	4

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	7.8E-01	1.0E+01 EG&G
Pu-238	1.4E-01	
Pu-239	5.9E+00	
Pu-240	9.4E-01	
Pu-241	9.5E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	1.5	10%	1.7	10%	0.7	10%
Pu-238	0.2	2%	0.3	2%	0.1	2%
Pu-239	11.6	75%	13.0	75%	5.3	75%
Pu-240	1.8	12%	2.1	12%	0.8	12%
Pu-241	0.3	2%	0.4	2%	0.1	2%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	15.5		17.4		7.1	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: TM101 - Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	0.25
Pu-238/239,240	0.02	Class Y	0.75
Pu-239/Am-241	7.6 ARL/TR80		
Pu-240/Am-241	1.2 ARL/TR80		
Pu-241/Am-241	12.1		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	4

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	7.8E-02	1.0E+00 EG&G
Pu-238	1.4E-02	
Pu-239	5.9E-01	
Pu-240	9.4E-02	
Pu-241	9.5E-01	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	10%	0.2	10%	0.1	10%
Pu-238	0.0	2%	0.0	2%	0.0	2%
Pu-239	1.2	75%	1.3	75%	0.5	75%
Pu-240	0.2	12%	0.2	12%	0.1	12%
Pu-241	0.0	2%	0.0	2%	0.0	2%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	1.5		1.7		0.7	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Kuli - U-238 D contour (ca. 0.02 sq.km) KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	N/A
Pu-238/239,240	N/A	Class Y	N/A
Pu-239/Am-241	N/A		
Pu-240/Am-241	N/A		
Pu-241/Am-241	N/A		
U-234/U-238	1 natural uranium	Depth factor	1
U-235/U-238	0.048 natural uranium	Enhancement factor	6

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m <sup>2</sup>
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	0.0E+00	
Pu-238	0.0E+00	
Pu-239	0.0E+00	
Pu-240	0.0E+00	
Pu-241	0.0E+00	
U-234	8.8E+00	
U-235	4.2E-01	
U-238	8.8E+00	1.5E+02 EG&G

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.0	0%	0.0	0%	0.0	0%
Pu-238	0.0	0%	0.0	0%	0.0	0%
Pu-239	0.0	0%	0.0	0%	0.0	0%
Pu-240	0.0	0%	0.0	0%	0.0	0%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	5.8	51%	8.6	51%	5.8	52%
U-235	0.3	2%	0.4	2%	0.3	2%
U-238	5.2	46%	7.8	46%	5.1	46%
TOTAL	11.2		16.9		11.2	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Kuli - U-238 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	N/A		
Am-241/Cs-137	N/A	Class W	N/A
Pu-238/239,240	N/A	Class Y	N/A
Pu-239/Am-241	N/A		
Pu-240/Am-241	N/A		
Pu-241/Am-241	N/A		
U-234/U-238	1 natural uranium	Depth factor	1
U-235/U-238	0.048 natural uranium	Enhancement factor	6

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	0.0E+00	
Cs-137	0.0E+00	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	0.0E+00	
Pu-238	0.0E+00	
Pu-239	0.0E+00	
Pu-240	0.0E+00	
Pu-241	0.0E+00	
U-234	1.0E+00	
U-235	4.8E-02	
U-238	1.0E+00	1.7E+01 EG&G

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.0	0%	0.0	0%	0.0	0%
Pu-238	0.0	0%	0.0	0%	0.0	0%
Pu-239	0.0	0%	0.0	0%	0.0	0%
Pu-240	0.0	0%	0.0	0%	0.0	0%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.7	51%	1.0	51%	0.7	52%
U-235	0.0	2%	0.0	2%	0.0	2%
U-238	0.6	46%	0.9	46%	0.6	46%
TOTAL	1.3		1.9		1.3	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Emu - Totem I ground zero

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	0.18 ARL/TR12		
Am-241/Cs-137	0.2 ARL/TR5	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	40 ARL/TR80		
Pu-240/Am-241	4.6		
Pu-241/Am-241	7.1		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	1

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	2.7E-01	
Cs-137	1.5E+00	
Co-60	1.6E-01 ARL/TR70	
Ba-133	8.0E-02 ARL/TR70	
Eu-152	2.0E+00 ARL/TR70	
Eu-154	1.3E-01 ARL/TR70	
Eu-155	1.5E-01 ARL/TR70	
Am-241	3.0E-01 ARL/TR70	
Pu-238	1.7E-01	
Pu-239	1.2E+01	
Pu-240	1.4E+00	
Pu-241	2.1E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	2%	0.1	2%	0.1	2%
Pu-238	0.0	1%	0.1	1%	0.0	1%
Pu-239	3.4	86%	4.5	86%	2.1	86%
Pu-240	0.4	10%	0.5	10%	0.2	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	4.0		5.2		2.4	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Emu - Totem II ground zero

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu
Sr-90/Cs-137	0.18 ARL/TR12	
Am-241/Cs-137	0.4 ARL/TR5	Class W 0
Pu-238/239,240	0.013	Class Y 1
Pu-239/Am-241	50 ARL/TR80	
Pu-240/Am-241	5.7	
Pu-241/Am-241	6.9	
U-234/U-238	N/A	Depth factor 1
U-235/U-238	N/A	Enhancement factor 1

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	4.5E-01	
Cs-137	2.5E+00	
Co-60	1.5E-01 ARL/TR70	
Ba-133	1.4E-01 ARL/TR70	
Eu-152	1.5E+00 ARL/TR70	
Eu-154	1.1E-01 ARL/TR70	
Eu-155	2.7E-01 ARL/TR70	
Am-241	1.0E+00 ARL/TR70	
Pu-238	7.2E-01	
Pu-239	5.0E+01	
Pu-240	5.7E+00	
Pu-241	6.9E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.3	2%	0.4	2%	0.2	2%
Pu-238	0.2	1%	0.3	1%	0.1	1%
Pu-239	14.3	87%	18.6	87%	8.6	87%
Pu-240	1.6	10%	2.1	10%	1.0	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	16.4		21.4		9.9	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Breakaway ground zero

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	0.48 ARL/TR5		
Am-241/Cs-137	0.3 ARL/TR70	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	30 ARL/TR80		
Pu-240/Am-241	3.5		
Pu-241/Am-241	8.6		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	1

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	1.9E-01	
Cs-137	4.0E-01	
Co-60	7.2E-01 ARL/TR70	
Ba-133	1.5E-02 ARL/TR70	
Eu-152	6.2E+00 ARL/TR70	
Eu-154	4.4E-01 ARL/TR70	
Eu-155	7.0E-02 ARL/TR70	
Am-241	1.2E-01 ARL/TR70	
Pu-238	5.2E-02	
Pu-239	3.6E+00	
Pu-240	4.2E-01	
Pu-241	1.0E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.0	3%	0.0	3%	0.0	3%
Pu-238	0.0	1%	0.0	1%	0.0	1%
Pu-239	1.0	85%	1.3	85%	0.6	85%
Pu-240	0.1	10%	0.2	10%	0.1	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	1.2		1.6		0.7	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Biak ground zero

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

Sr-90/Cs-137	0.26 ARL/TR5	Chemical class of Am and Pu	
Am-241/Cs-137	0.5 ARL/TR70	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	40 ARL/TR80		
Pu-240/Am-241	4.6		
Pu-241/Am-241	9		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	1

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	2.2E-01	
Cs-137	8.4E-01	
Co-60	2.7E-01 ARL/TR70	
Ba-133	1.0E-02 ARL/TR70	
Eu-152	2.3E+00 ARL/TR70	
Eu-154	1.8E-01 ARL/TR70	
Eu-155	1.8E-01 ARL/TR70	
Am-241	4.2E-01 ARL/TR70	
Pu-238	2.4E-01	
Pu-239	1.7E+01	
Pu-240	1.9E+00	
Pu-241	3.8E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
		%		%		%
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	2%	0.2	2%	0.1	2%
Pu-238	0.1	1%	0.1	1%	0.0	1%
Pu-239	4.8	86%	6.2	86%	2.9	86%
Pu-240	0.6	10%	0.7	10%	0.3	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	5.6		7.2		3.3	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Tadge ground zero

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

ASSUMED RATIOS OF ACTIVITIES		Chemical class of Am and Pu	
Sr-90/Cs-137	0.61 ARL/TR5		
Am-241/Cs-137	2.2 ARL/TR70	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	40 ARL/TR80		
Pu-240/Am-241	5.7 ARL/TR80		
Pu-241/Am-241	9		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	1

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	8.6E-01	
Cs-137	1.4E+00	
Co-60	2.0E-01 ARL/TR70	
Ba-133	1.0E-02 ARL/TR70	
Eu-152	4.0E-01 ARL/TR70	
Eu-154	4.0E-02 ARL/TR70	
Eu-155	2.1E-01 ARL/TR70	
Am-241	3.1E+00 ARL/TR70	
Pu-238	1.8E+00	
Pu-239	1.2E+02	
Pu-240	1.8E+01	
Pu-241	2.8E+01	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.9	2%	1.2	2%	0.5	2%
Pu-238	0.5	1%	0.7	1%	0.3	1%
Pu-239	35.4	84%	46.0	84%	21.4	84%
Pu-240	5.0	12%	6.6	12%	3.0	12%
Pu-241	0.1	0%	0.2	0%	0.1	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	42.0		54.6		25.3	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: One Tree ground zero

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	0.24 ARL/TR5		
Am-241/Cs-137	0.2 ARL/TR5	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	30 ARL/TR80		
Pu-240/Am-241	3.5		
Pu-241/Am-241	8.6		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	1

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m <sup>2</sup>
Sr-90	3.1E-01	
Cs-137	1.3E+00	
Co-60	6.8E-01 ARL/TR70	
Ba-133	1.0E-02 ARL/TR70	
Eu-152	5.4E+00 ARL/TR70	
Eu-154	4.9E-01 ARL/TR70	
Eu-155	2.2E-01 ARL/TR70	
Am-241	2.6E-01 ARL/TR70	
Pu-238	1.1E-01	
Pu-239	7.8E+00	
Pu-240	9.1E-01	
Pu-241	2.2E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	3%	0.1	3%	0.0	3%
Pu-238	0.0	1%	0.0	1%	0.0	1%
Pu-239	2.2	85%	2.9	85%	1.3	85%
Pu-240	0.3	10%	0.3	10%	0.2	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	2.6		3.4		1.6	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Emu - Totem I Cs-137 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

ASSUMED RATIOS OF ACTIVITIES		Chemical class of Am and Pu	
Sr-90/Cs-137	0.1 ARL/TR12		
Am-241/Cs-137	0.2 ARL/TR5	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	40 ARL/TR80		
Pu-240/Am-241	4.6		
Pu-241/Am-241	7.1		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	2

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	3.5E-03	
Cs-137	3.5E-02	6.0E-01 EG&G
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	7.1E-03	
Pu-238	4.1E-03	
Pu-239	2.8E-01	
Pu-240	3.2E-02	
Pu-241	5.0E-02	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
	0.0	0%	0.0	0%	0.0	0%
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.0	2%	0.0	2%	0.0	2%
Pu-238	0.0	1%	0.0	1%	0.0	1%
Pu-239	0.2	86%	0.2	86%	0.1	86%
Pu-240	0.0	10%	0.0	10%	0.0	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	0.2		0.2		0.1	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Emu - Totem I Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	0.1 ARL/TR12	Class W	0
Am-241/Cs-137	0.2 ARL/TR5	Class Y	1
Pu-238/239,240	0.013		
Pu-239/Am-241	40 ARL/TR80		
Pu-240/Am-241	4.6		
Pu-241/Am-241	7.1		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	2

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	7.8E-02	
Cs-137	7.8E-01	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	1.6E-01	2.0E+00 EG&G
Pu-238	9.1E-02	
Pu-239	6.3E+00	
Pu-240	7.2E-01	
Pu-241	1.1E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
	Dose	%	Dose	%	Dose	%
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	2%	0.1	2%	0.1	2%
Pu-238	0.0	1%	0.1	1%	0.0	1%
Pu-239	3.6	86%	4.6	86%	2.2	86%
Pu-240	0.4	10%	0.5	10%	0.2	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	4.1		5.4		2.5	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Emu - Totem II Cs-137 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

ASSUMED RATIOS OF ACTIVITIES		Chemical class of Am and Pu	
Sr-90/Cs-137	0.1 ARL/TR12		
Am-241/Cs-137	0.4 ARL/TR5	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	50 ARL/TR80		
Pu-240/Am-241	5.7		
Pu-241/Am-241	6.9		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	2

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m <sup>2</sup>
Sr-90	3.5E-03	
Cs-137	3.5E-02	6.0E-01 EG&G
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	1.4E-02	
Pu-238	1.0E-02	
Pu-239	7.1E-01	
Pu-240	8.0E-02	
Pu-241	9.7E-02	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
	0.0	0%	0.0	0%	0.0	0%
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.0	2%	0.0	2%	0.0	2%
Pu-238	0.0	1%	0.0	1%	0.0	1%
Pu-239	0.4	87%	0.5	87%	0.2	87%
Pu-240	0.0	10%	0.1	10%	0.0	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	0.5		0.6		0.3	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Emu - Totem II Am-241 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

ASSUMED RATIOS OF ACTIVITIES		Chemical class of Am and Pu	
Sr-90/Cs-137	0.1 ARL/TR12		
Am-241/Cs-137	0.4 ARL/TR5	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	50 ARL/TR80		
Pu-240/Am-241	5.7		
Pu-241/Am-241	6.9		
U-234/U-238	N/A	Depth factor	1.33
U-235/U-238	N/A	Enhancement factor	2

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m <sup>2</sup>
Sr-90	3.9E-02	
Cs-137	3.9E-01	
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	1.6E-01	2.0E+00 EG&G
Pu-238	1.1E-01	
Pu-239	7.8E+00	
Pu-240	8.9E-01	
Pu-241	1.1E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
		%		%		%
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.1	2%	0.1	2%	0.1	2%
Pu-238	0.1	1%	0.1	1%	0.0	1%
Pu-239	4.5	87%	5.8	87%	2.7	87%
Pu-240	0.5	10%	0.7	10%	0.3	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	5.1		6.7		3.1	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Maralinga - Cs-137 A contour

KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

ASSUMED RATIOS OF ACTIVITIES		Chemical class of Am and Pu	
Sr-90/Cs-137	0.24 ARL/TR5		
Am-241/Cs-137	0.2 ARL/TR5	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	30 ARL/TR80		
Pu-240/Am-241	3.5		
Pu-241/Am-241	8.6		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	2

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m <sup>2</sup>
Sr-90	4.2E-03	
Cs-137	1.8E-02	3.0E-01 EG&G
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	3.5E-03	
Pu-238	1.5E-03	
Pu-239	1.1E-01	
Pu-240	1.2E-02	
Pu-241	3.0E-02	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION mSv/y

	ADULTS		CHILDREN		INFANTS	
	0.0	0%	0.0	0%	0.0	0%
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.0	3%	0.0	3%	0.0	3%
Pu-238	0.0	1%	0.0	1%	0.0	1%
Pu-239	0.1	85%	0.1	86%	0.0	86%
Pu-240	0.0	10%	0.0	10%	0.0	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	0.1		0.1		0.0	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Maralinga fallout field, 2nd Av./Right St. KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

		Chemical class of Am and Pu	
Sr-90/Cs-137	0.24 ARL/TR5		
Am-241/Cs-137	N/A	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	30 ARL/TR80		
Pu-240/Am-241	3.5		
Pu-241/Am-241	8.6		
U-234/U-238	N/A	Depth factor (Am)	1.33
U-235/U-238	N/A	Enhancement factor	2

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	9.2E-02	
Cs-137	3.8E-01	6.5E+00 EG&G
Co-60	0.0E+00	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	0.0E+00	
Am-241	2.8E-01	3.6E+00 EG&G
Pu-238	1.2E-01	
Pu-239	8.4E+00	
Pu-240	9.9E-01	
Pu-241	2.4E+00	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.2	3%	0.2	3%	0.1	3%
Pu-238	0.1	1%	0.1	1%	0.0	1%
Pu-239	4.8	86%	6.3	86%	2.9	86%
Pu-240	0.6	10%	0.7	10%	0.3	10%
Pu-241	0.0	0%	0.0	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	5.6		7.3		3.4	

## SPREADSHEET FOR INHALATION DOSE ASSESSMENT

SITE: Contaminated area ca. 500 m NNE of Tadge KHL/GW 17 APR 1990

## ASSUMED RATIOS OF ACTIVITIES

ASSUMED RATIOS OF ACTIVITIES		Chemical class of Am and Pu	
Sr-90/Cs-137	0.61 ARL/TR5		
Am-241/Cs-137	3.6 ch.4	Class W	0
Pu-238/239,240	0.013	Class Y	1
Pu-239/Am-241	40 ARL/TR80		
Pu-240/Am-241	5.7 ARL/TR80		
Pu-241/Am-241	9		
U-234/U-238	N/A	Depth factor	1
U-235/U-238	N/A	Enhancement factor	0.3

## CONCENTRATIONS IN SOIL

NUCLIDE	Bq/g (top 10 mm)	kBq/m2
Sr-90	6.1E-01	
Cs-137	1.0E+00 Table 4.11, ch.4	
Co-60	1.2E-01 Table 4.11, ch.4	
Ba-133	0.0E+00	
Eu-152	0.0E+00	
Eu-154	0.0E+00	
Eu-155	1.5E-01 Table 4.11, ch.4	
Am-241	3.5E+00 Table 4.11, ch.4	
Pu-238	2.1E+00	
Pu-239	1.4E+02	
Pu-240	2.0E+01	
Pu-241	3.2E+01	
U-234	0.0E+00	
U-235	0.0E+00	
U-238	0.0E+00	

## ASSESSED DOSE FROM INHALATION

mSv/y

	ADULTS		CHILDREN		INFANTS	
Sr-90	0.0	0%	0.0	0%	0.0	0%
Cs-137	0.0	0%	0.0	0%	0.0	0%
Co-60	0.0	0%	0.0	0%	0.0	0%
Ba-133	0.0	0%	0.0	0%	0.0	0%
Eu-152	0.0	0%	0.0	0%	0.0	0%
Eu-154	0.0	0%	0.0	0%	0.0	0%
Eu-155	0.0	0%	0.0	0%	0.0	0%
Am-241	0.3	2%	0.4	2%	0.2	2%
Pu-238	0.2	1%	0.2	1%	0.1	1%
Pu-239	12.2	84%	15.8	84%	7.3	84%
Pu-240	1.7	12%	2.3	12%	1.0	12%
Pu-241	0.0	0%	0.1	0%	0.0	0%
U-234	0.0	0%	0.0	0%	0.0	0%
U-235	0.0	0%	0.0	0%	0.0	0%
U-238	0.0	0%	0.0	0%	0.0	0%
TOTAL	14.4		18.8		8.7	

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