2
25-74

DA-816

LA-5579-PR

Progress Report

Progress Report

**Contamination Limits for Real and
Personal Property**

July - December 1973

**los alamos
scientific laboratory**

of the University of California

LOS ALAMOS, NEW MEXICO 87544

UNITED STATES
ATOMIC ENERGY COMMISSION
CONTRACT W-7405-ENG. 36

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

This report presents the status of the program on Contamination Limits for Real and Personal Property. The most recent report in this series, unclassified, is:

LA-5482-PR

In the interest of prompt distribution, this progress report was not edited by the Technical Information staff.

Printed in the United States of America. Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy \$4.00 Microfiche \$1.45

LA-5579-PR
Progress Report
UC-41
Issued: April 1974

Progress Report
Contamination Limits for Real and
Personal Property
July - December 1973

by

J. W. Healy
W. J. Smith

This work supported by the U.S. Atomic Energy Com-
mission's Division of Operational Safety.

MASTER

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

CONTAMINATION LIMITS FOR REAL AND PERSONAL PROPERTY

Progress Report for the Period of

July - December 1973

by

J. W. Healy and W. J. Smith

ABSTRACT

A summary of the work performed during this period along with some needed programs to obtain additional data are given. A brief description of the preliminary standard for plutonium in soils along with progress on a calculation of the FIDLER calibration and a conceptual model for contamination transfer from an object to the body are included.

The early part of this period was devoted to finishing several of the studies described in the last report¹ and applying them to a derivation of a preliminary standard for plutonium in soils. This work was documented² and attention was turned to the question of contamination of objects to be transferred to public use and the resulting potential internal and external radiation doses. A full time staff member joined the project during the last half of the period with his attention currently devoted to the surface contamination question.

This report summarizes the results of the work during the period. In contrast to the last report, details are omitted and only salient results are described. It is intended that the complete derivations and results will be presented in topical reports.

I. PLUTONIUM IN SOILS - J. W. Healy

A proposed interim standard for plutonium in soils as based upon potential health consequences was derived and documented.² This work also resulted in the partial completion of studies on resuspension and methods of computing concentrations in the atmosphere from resuspension; on the deposition of aerosols from turbulent clouds; and on the

effectiveness of radioactive particles in the lung in producing cancer as compared to a uniform dose distribution.

The standard was derived for continuous occupancy of a region containing plutonium in the soils, with the parameters used generally those for a type of area where maximum transfers of plutonium from soils to intake by man would be expected. No attempt was made to formulate a formal "risk" model since the data available would not permit definition of the transfer coefficients under the many different conditions possible. Instead, the derivations were based upon the maximum permissible limits recommended by the various national and international bodies expert in such matters. The purpose of the standard is to provide values to be used in control of a given situation, or in conducting operations which could lead to contamination of the soils. The numbers can be related to radiation dose or the effects of such dose only indirectly and with uncertainty of many orders of magnitude depending upon the individual situation. For this reason, attempts should not be made to use the numerical values given in the standard to attempt estimates of dose to individuals living in a contaminated area.

TABLE I
PROPOSED INTERIM STANDARDS FOR
PLUTONIUM IN SOILS

	In <100 μ m particle size fraction			Total**	
	Dis/min per g	μ Ci/g	μ Ci/m ²	μ Ci/g	μ Ci/m ²
Top layer*	500	2×10^{-4}	0.4	4×10^{-4}	0.8
Any one cm layer	500	2×10^{-4}	0.4	4×10^{-4}	8

*For bare or sparsely vegetated areas, the top layer is arbitrarily taken as 1 mm. Where the area is reasonably well vegetated with 50% or more of the area covered with vegetation and a reasonable root mat exists to hold the soil, this may be increased to an arbitrary 0.5 cm layer.

**With the provision that the fraction with particle sizes less than 100 μ m is known not to exceed the limits given. If this is not known, the values for the <100 μ m fraction should be applied to the total.

An attempt was made to include specifications on both the particle size of the contaminant and the thickness of the layer of soil contaminated, both being parameters which should have a profound influence on the eventual transfer to man. Since information on the effect of particle size on the various transfer mechanisms and the importance of the depth of burial under different conditions is not available, the limitations placed on these quantities are largely arbitrary in nature based more on deductive reasoning than on mathematical formulations. While this, again, provides a degree of uncertainty in the overall accuracy of the limitation prescribed, it does permit consideration of these important variables in making measurements in an area and, hopefully, will focus some attention on them and their role in future studies. A summary of the values derived is given in Table I.

The continuous occupancy basis was used since occupancy characteristics of a given area vary greatly with time; a grazing area today may be a residential subdivision tomorrow. However, in situations where long term control seems probable, compensatory increases in the numerical values would seem possible.

Current plans are to circulate the document to a group of people with specific requests for comments. These will, then, be considered and incorporated into a second version. It is believed that further study will result in standards more applicable to specific types of areas such as heavily vegetated areas, forest land or similar areas where transfer to man is less likely than the desert areas

used to consider the parameters. With additional data, it may also be reasonable to increase the recommended values.

II. FIDLER CALIBRATION - W. J. Smith

The FIDLER (Field Instrument for Detection of Low Energy Radiation) was originally developed to permit measurement of plutonium contamination following an accident. Under such conditions, with early measurement, the plutonium is largely on or near the soil surface, although sufficient downward migration occurs to make measurements with alpha detectors extremely uncertain. Measurement of the more penetrating 17 keV x rays from plutonium and 60 keV gamma rays from americium permits the reduction of this uncertainty with, however, a severe penalty in the sensitivity of the measurement.

This instrument has gained favor for field measurements in many situations where the soil plutonium content is well above the fallout background. Direct measurement of the plutonium x rays may be made, or measurements may be made of the higher energy gamma rays, from the associated americium, with the relationship between americium and plutonium determined from other information. For example, the isopleths at the GMX area in Nevada, which were used in the initial appraisal of resuspension in the last report of this series,¹ were obtained from FIDLER surveys of the ²⁴¹Am. However, only a few chemical analyses were available at that time for the americium-plutonium correlation and the sensitivity of the instrument for various plutonium profiles was not well known. As a result, the measurement of the source term for the calculations to estimate the pickup rate was very uncertain.

Because of the potential use of this instrument for routine measurements or research studies, a theoretical study of its response was undertaken in order to obtain an understanding of its behavior under various contamination situations. These results will provide a basis for interpreting results from the literature, and for investigating the importance of a number of variables to the instrument response.

The FIDLER detector is a 12.7-cm-diameter by 0.16-cm-thick crystal of NaI(Tl) which is optically coupled to a photomultiplier tube. The crystal and photomultiplier tube are housed in stainless steel, with the exception of the counting face of the crystal which is covered by 0.025 cm of beryllium. More detailed descriptions of this instrument are available elsewhere.^{3,4} Those portions of its design which are of interest here are the circular crystal face with its beryllium cover, and the flange of the stainless steel casing which projects slightly below the crystal. A point source not directly below the FIDLER face will be partially shielded from the crystal due to the stainless steel flange. These shielded portions of the crystal will be ineffective in detecting the low energy photons from the point source.

In this study an expression for the geometry of the FIDLER was derived for a point source on or off the axis of the crystal and at any specified vertical distance from the counter face, taking into account the portion of the crystal shielded by the flange. This expression is given in Eq. (1).

$$\Omega = 2C \int_x^{x_0 + a_1} \frac{\left[a_1^2 - (x' - x_0)^2 \right]^{1/2}}{\left[(x')^2 + (C + d)^2 \right]^{3/2}} dx' \\ + 2C \int_x^{x_0 + s - a_2} \frac{\left[a_2^2 - (x' - (x_0 + s))^2 \right]^{1/2}}{\left[(x')^2 + (C + d)^2 \right]^{3/2}} dx' \quad (1)$$

Where C = the height of the FIDLER above the ground;
d = the depth of the point source within the ground;
a₁ = radius of crystal;
a₂ = radius of projection of the flange on the plane of the crystal face;
x₀ = the center of the crystal face;
x = a reference location on the crystal face;
x' = the variable of integration over the crystal face; and

s = distance from center of crystal to center of projection of flange.

This expression was corrected for the absorption in the intervening layers of soil, air, and beryllium. The absorption correction was derived using the angles and distances between the point source and the center of the crystal. Due to the finite size of the crystal, this must be indicated as an approximation, albeit one which is not serious for the purposes of this calculation. The counting rate due to a point source of activity "A" disintegrations per unit time is given in Eq. (2).

$$c/m = \Omega A e^{-\mu_s x_s} e^{-\mu_a x_a} e^{-\mu_b x_b} (1 - e^{-\mu_n x_n}) \quad (2)$$

Where Ω = the geometry from Eq. (1);

$\mu_{s,a,b,n}$ = absorption coefficients for soil, air, beryllium, and NaI; and

$x_{s,a,b,n}$ = thicknesses of the above materials intervening between source and detector, taking into account the slant thickness for off-center sources.

For calculating the counting rate from an area source centered below the detector, the response to a series of co-planar point sources located radially outward from the axis of the counter was determined. Each of these points was weighted by the area of the annulus which it represented, and summed with the weighted responses from all other points. A good approximation to an area response is obtained in the limit that the distance between the points is sufficiently small (or the annuli sufficiently thin).

These equations were programmed for a Wang 600 programmable calculator so that the response from point and planar sources buried at various depths could be obtained. No attempt was made to provide integration through the soil profile since such profiles vary widely. Instead, the integration with depth will be done by hand for the profiles of interest.

Several trial evaluations of the program have been made using the constants given in Table II.

TABLE II

CONSTANTS FOR PRELIMINARY EVALUATION

Flange depth ----- 0.125 cm

 ^{241}Am 17 keV photons/dis -- 0.376

60 keV photons/dis -- 0.376

 ^{239}Pu 17 keV photons/dis -- 0.04

	Density g/cm ³	Absorption Coefficient ⁵	
		cm ² /g	
		17keV	60 keV
Air	0.001293	1.54	0.186
Beryllium	1.8	0.296	0.150
Soil	1.6	* 8.26	* 0.290

* For preliminary evaluation absorption coefficient for concrete was used since μ/ρ for soil will change with composition.

A comparison with experimental values for a 10.7 μCi ^{241}Am point source⁴ at various radial distances from the center of the counter with the distance from the counter face to the source plane of 30.5 cm was done. The results of this comparison are given in Table III.

The variation of counting rate with depth in the soil profile was investigated for both the 17-keV x ray and the 60-keV gamma ray. These results are given in Tables IV and V for a uniform distribution of 1 $\mu\text{Ci}/\text{cm}^3$ of ^{241}Am in the soil profile.

From Table IV it is noted that 90% of the response to the 17-keV photons used for the plutonium measurement arises from the first 200 mg/cm^2 layer of the soil while from Table V a similar depth for the 60-keV photons used for ^{241}Am is about 5500 mg/cm^2 .

TABLE III

COMPARISON OF CALCULATED AND EXPERIMENTAL

RESULTS FOR A 10.7 μCi ^{241}Am SOURCE

30.5 CM FROM COUNTER FACE

Radial Distance cm	17 keV Channel		60 keV Channel	
	Measured c/m	Calculated c/m	Measured c/m	Calculated c/m
0	8.5×10^4	8.8×10^4	7.2×10^4	-
5	7.5×10^4	8.5×10^4	6.5×10^4	5.8×10^4
15	6.0×10^4	6.4×10^4	5.0×10^4	4.7×10^4
25	5.3×10^4	4.1×10^4	3.7×10^4	3.2×10^4
35	4.0×10^4	2.4×10^4	2.5×10^4	2.1×10^4
45	1.4×10^4	1.5×10^3	1.2×10^4	1.4×10^4
60	7.2×10^3	7.5×10^3	6.4×10^3	7.8×10^3
75	3.9×10^3	4.1×10^3	3.3×10^3	4.5×10^3
90	2.3×10^3	2.5×10^2	2.1×10^2	3.0×10^3
125	1.0×10^3	8.7×10^2	9.0×10^2	1.1×10^2
150	5.0×10^2	4.5×10^2	4.3×10^2	6.5×10^2
185	3.0×10^2	2.3×10^2	2.3×10^2	3.5×10^2
215	1.7×10^2	1.4×10^1	1.6×10^2	2.2×10^2
245	1.0×10^2	8.4×10^1	1.0×10^2	1.5×10^2

TABLE IV

VARIATION OF FIDLER RESPONSE IN 17 keV CHANNEL
WITH DEPTH IN SOIL PROFILE. SOURCE IS 1 $\mu\text{Ci}/\text{cm}^3$
OF ^{241}Am OR ABOUT 1.4×10^6 DIS/MIN PER GRAM

Depth of Layer		Response to Layer	Cumulative Response
mg/cm ²	cm	c/m	%
0-40	0.000 - 0.025	7.3×10^5	42.8
40-120	0.025 - 0.075	5.9×10^5	77.4
120-200	0.075 - 0.125	2.2×10^5	90.3
200-280	0.125 - 0.175	9.2×10^4	95.7
280-360	0.175 - 0.225	4.0×10^4	98.0
360-440	0.225 - 0.275	1.8×10^4	99.1
440-520	0.275 - 0.325	8.1×10^3	99.58
520-600	0.325 - 0.375	3.7×10^3	99.8
600-380	0.375 - 0.425	1.7×10^3	99.9
Total		1.7×10^6	100

During the next period the program will be used to investigate the effects of such variables as height from the ground, soil composition, certain non-uniform distributions, and several selected profiles.

TABLE V

VARIATION OF FIDLER RESPONSE IN 60 keV CHANNEL
WITH DEPTH IN SOIL PROFILE. SOURCE IS 1 $\mu\text{Ci}/\text{cm}^3$
OF ^{241}Am OR ABOUT 1.4×10^6 DIS/MIN PER GRAM

Depth of Layer		Response to Layer	Cumulative Response
mg/cm ²	cm	c/m	%
0-160	0.0 - 0.1	3.3×10^6	7.9
160-580	0.1 - 0.3	5.8×10^6	21.7
580-800	0.3 - 0.5	4.8×10^6	33.1
800-1120	0.5 - 0.7	4.0×10^6	42.6
1120-1440	0.7 - 0.9	3.2×10^6	50.3
1440-1760	0.9 - 1.1	2.8×10^6	56.9
1760-2180	1.1 - 1.3	2.4×10^6	62.7
2180-2400	1.3 - 1.5	2.0×10^6	67.4
2400-2720	1.5 - 1.7	1.7×10^6	71.5
2720-3040	1.7 - 1.9	1.5×10^6	75.1
3040-3360	1.9 - 2.1	1.3×10^6	78.2
3360-3880	2.1 - 2.3	1.1×10^6	80.8
3880-4000	2.3 - 2.5	9.6×10^5	83.1
4000-4320	2.5 - 2.7	8.4×10^5	85.1
4320-4640	2.7 - 2.9	7.4×10^5	86.8
4640-4960	2.9 - 3.1	6.4×10^5	88.3
4960-5380	3.1 - 3.3	5.6×10^5	89.7
5380-5600	3.3 - 3.5	5.0×10^5	90.9
5600-7200	3.5 - 4.5	1.7×10^6	95.0
7200-12,350	4.5 - 7.75	1.8×10^6	99.3
Total		4.2×10^7	100

III. CONTAMINATION TRANSFER FROM OBJECTS -

W. J. Smith and J. W. Healy

In the derivation of limits for surface contamination on personal property, an understanding of the possible transfer of the radioactive material to man, air, water, and other objects is necessary before a description of the limiting mechanisms of exposure can be derived. While there have been studies of some of the individual transfer mechanisms under specific conditions, little attention has been paid to a more general and fundamental description. As an initial phase in this study, we have started to investigate a basic, conceptual model which, hopefully, will aid in defining the types of information needed to provide an adequate knowledge of these transfer mechanisms.

In the first step, we have considered the transfer from a contaminated object to the body, or, by suitable definition of terms, to other objects which may be contacted. Equation (3) is a differential equation representing the quantity transferred from the contaminated object to the body.

$$dQ_B = f_t A_s C_s dt - f_L Q_B dt, \quad (3)$$

Q_B = quantity of contamination on the body at any time (μCi);

A_s = area of the contaminated object contacted by the body (cm^2);

C_s = quantity of contamination per unit area on the object ($\mu\text{Ci}/\text{cm}^2$);

f_t = fraction of contamination transferred to the body per unit time by the contacts;

f_L = fraction of contamination lost from the body per unit time from all mechanisms.

Implicit in this description is the assumption that losses from the object by mechanisms other than contact with the body are small. If this is not the case (as for example if part of the loss of contamination from the object is by transfer to another object), then the f_t term becomes one of several terms describing the total loss from the surface.

The transfer functions f_t and f_L are immediately apparent as the major unknowns not only in magnitude but also in their dependency on time. If one considers the situation where the transfer from the object to the body occurs as a result of a series of repeated contacts, the f_t coefficient can be written as:

$$f_t = \frac{\text{contacts}}{\text{time}} \frac{\text{fraction transferred}}{\text{contact}}. \quad (4)$$

For situations where the contacts per times can be defined as a function of time through time and motion studies or other means, the major question of the fraction transferred per contact remains. While one would expect that this could depend on such factors as the nature of the contacting surfaces or the amount of pressure and motion, this remains a key variable which will be difficult to define in a quantitative fashion. An assumption that a fixed fraction is removed per contact would lead to an exponential type of decrease in the surface contamination and would provide a simple equation for evaluation. However, this would imply a simple bonding model for the material to the surface with ready exchange between the portion "fixed" to the surface and that which is removed. Intuitively, one would feel that the more usual situation would be one in which the fraction transferred per contact would decrease with time. This could be modeled by a series of transfer rates or a power function dependence of time. A simpler approximation could be to consider only two fractions, "loose" contamination and "fixed" contamination where the "loose" contamination is considered to transfer by a function characteristic of the radioactive material and the surface with the "fixed" contamination transfer rate related to the rate of wear of the surface. A possible "worst case" evaluation would be to consider the term $(f_t A_s C_s)$ as the quantity of material removed on each pass without considering the resultant decrease in surface contamination level. This could be evaluated by a single "swipe" measurement.

During the next period the implications of this type model will be further developed with investigation of the possibility of relating the concepts to

simple measurement techniques. Where possible parametric studies will be made to investigate the sensitivity to individual variables or the dependency of such variables on time.

IV. INFORMATION NEEDS - J. W. Healy

The assessment of information needs and experimental programs to answer questions of missing and inadequate data is considered to be an important part of the overall program. Iterative studies using the results from such programs in revising past conclusions will aid in reducing uncertainty in the final results and will provide full justification of the procedures and assumptions. To this end, we plan to include discussions of needed information and possible programs in the periodic reports.

Experimental work to better define transfer mechanisms and coefficients for the movement of contamination from surfaces to people or other items is badly needed if reasonably justified limits for surface contamination are to be derived. Such work would include defining the degree of tenacity with which a given material adheres to a surface and, hopefully, simple tests which could be applied in the field. Past attempts at this problem have shown considerable ingenuity but generally have been sporadic with no sustained effort. The need for such work has been recognized and one of the objectives of the conceptual study described earlier is to permit more concrete definition of the type of program needed. One specific piece of information recognized from the study of plutonium in soils is the transfer of contaminant from the soils to the clothing and persons of individuals moving or working in an area. Presumably this could be measured in existing areas where personnel are engaged in sampling or other work by sensitive and detailed measurement on clothing and tools after leaving an area. While this has been discussed with several groups, the requirements for such detailed measurements have been such that full support is difficult to obtain.

The question of wind resuspension with resulting concentrations in the atmosphere plays an important role in many discussions of contaminated areas. Associated with this in the determination

of the actual concentration is the rate of redeposition of particles once they become airborne. While equations relating the airborne concentrations to the contamination on the ground using existing meteorological formulations and correlations can be written, evaluation of the pickup and deposition parameters is difficult because of the lack of detailed information on the effect of such variables as particle sizes of both contaminant and soil, ground surface cover, terrain, condition of the soil and many others. Experimental work on the pickup parameter is in progress at Hanford by Battelle-Pacific Northwest Laboratory and at the Nevada Test Station by Lawrence Livermore Laboratory but the number of parameters which can be studied is limited by the necessarily large type of experiment needed and the time required. Numerical hydrodynamic techniques using computer simulation have been developed and applied, with apparent success, to such problems as atmospheric dispersion over short distances in uneven terrain or in the vicinity of buildings. An attempt should be made to use these techniques in both the pickup and later deposition problems. If even slight success is attained, it would permit the investigation of variables and their relative importance and would provide an improved basis for experimental work.

REFERENCES

1. J. W. Healy, "Contamination Limits for Real and Personal Property, Progress Report for the Period January to June 1973," U. S. Atomic Energy Commission document, LA-5482-PR (Los Alamos Scientific Laboratory) January 1974.
2. J. W. Healy, "A Proposed Interim Standard for Plutonium in Soils," U. S. Atomic Energy Commission document, LA-5483-MS (Los Alamos Scientific Laboratory) January 1974.
3. J. F. Tinney and J. J. Koch, "Hazards Control Progress Report No. 29," U. S. Atomic Energy Commission document, UCRL-50007-67-3 (Lawrence Livermore Laboratory) p. 6, 1967.
4. C. L. Lindeken and J. J. Koch, "Hazards Control Progress Report No. 31," U. S. Atomic Energy Commission document, UCRL-50007-69-1 (Lawrence Livermore Laboratory) p. 20, 1969.
5. E. Storm and H. I. Israel, "Photon Cross Sections from 0.001 to 100 MeV for Elements 1 Through 100," U. S. Atomic Energy Commission document, LA-3753 (Los Alamos Scientific Laboratory) November 1967.