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for Livermore Thoracic Phantom Lungs
Fabricated Using Contemporary Materials**

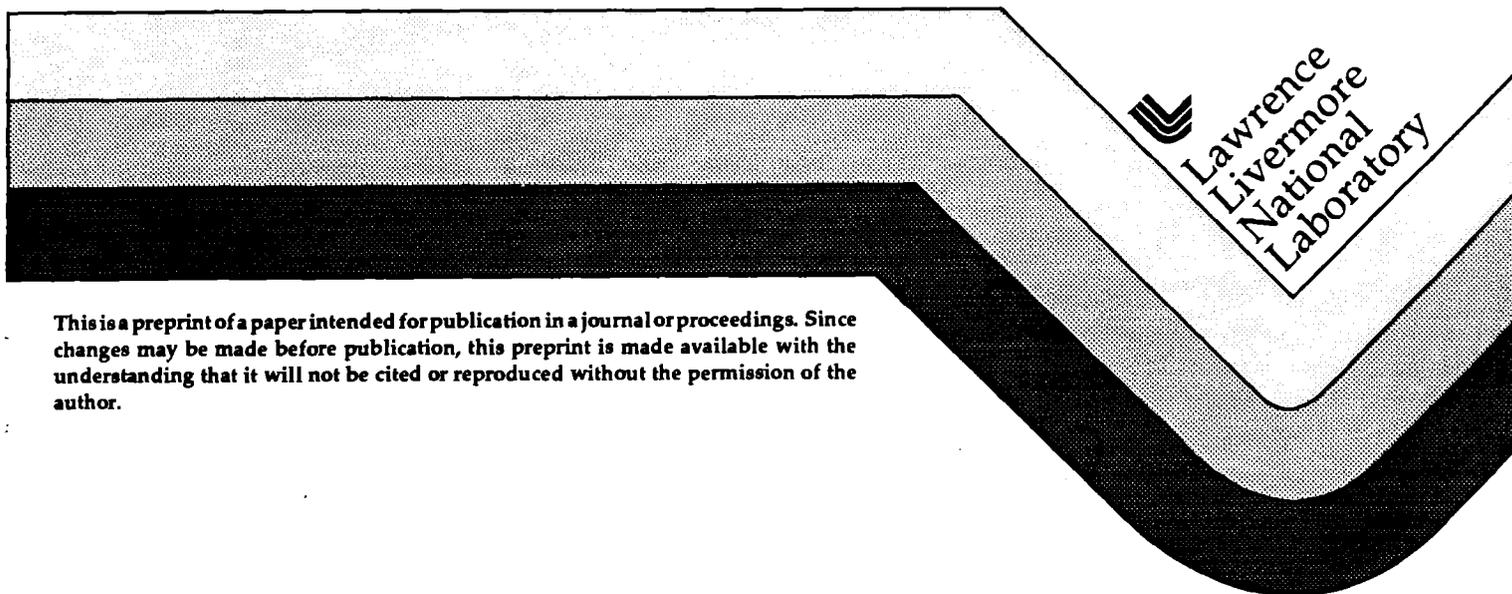
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Measurement of the Attenuation Coefficient for Livermore
Thoracic Phantom Lungs Fabricated Using Contemporary Materials

by

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ABSTRACT

The University of Cincinnati has reproduced the original formulation for the Livermore thoracic phantom lungs using contemporary materials and has adopted the linear attenuation coefficient as the primary quality assurance parameter for evaluating the performance capabilities of these new lung phantoms. The Livermore phantom was originally fabricated in 1978 to intercalibrate detector systems used to measure plutonium and other low-energy, photon emitting radionuclides deposited in the respiratory tract. The linear attenuation coefficient is a critical performance indicator for these phantom lungs since the presence of any material with a high effective atomic number (where $Z \geq 20$) will make a significant change in the photoelectric cross section, the predominant mode of interaction

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for plutonium X-rays. A set of test lungs was fabricated with KCl to introduce a known quantity of K^{40} in the phantom and to determine, by measurement and calculations, what change would be made to the attenuation coefficient at photon energies below 100 keV as a result of the modified formulation. The KCl increased the linear attenuation coefficient below 60 keV by more than a factor of two which would produce a substantial systematic error in any subsequent calibration measurements performed with these modified phantom lungs. These results support use of the attenuation coefficient as an important performance indicator for the Livermore phantom lungs and also suggest that KCl not be added to the lung tissue substitute formulation as a means to incorporate K^{40} in the phantom for low energy calibrations.

INTRODUCTION

The Livermore Thoracic Phantom provides a somewhat realistic, consensus calibration standard for measuring plutonium and other low energy photon-emitting radionuclides deposited in the respiratory tract (Dean 1976, Griffith, 1978). The need for such a phantom was originally based upon the requirement to more accurately evaluate the results of in vivo measurements for plutonium deposited in the lungs of workers. Routine in vivo measurements are an integral part of a comprehensive, internal radiation dosimetry monitoring program at DOE facilities where transuranic radioactive materials are

processed.

In vivo measurement of plutonium in the lungs has always been a technical challenge, even with the high resolution germanium detector systems available today (Toohey, 1991). These measurements typically involve placing an array of detectors on the anterior thorax of a person and detecting low energy x-rays and photons which penetrate the thoracic tissue. Accurate calibrations are particularly difficult to perform because low energy photons are easily attenuated by muscle, bone, and other adipose tissue (Swinth 1973, Swinth 1979). The Livermore thoracic phantom was developed to address some of these physical concerns while providing a device which is anatomically suitable for calibrating in vivo measurement systems. The selection of tissue substitute materials for use in the phantom involved developing chemical formulations for substitute organs and tissues which would exhibit the same attenuation coefficients at low energies as the original tissue.

Special emphasis in the design of the Livermore phantom was directed towards selection of a tissue substitute material for the lungs. In particular, these mock lungs had to have a density of 0.26 gm cm^{-3} and exhibit a linear attenuation coefficient similar to human lung below 20 keV, the predominant emission from plutonium. Attenuation at this energy is almost entirely produced by photoelectric interactions. Newton and White (Newton 1978) calculated the Compton and photoelectric attenuation coefficients for twenty-six types of lung tissue substitute

materials and found a considerable range of values for photon energies of 13.6 kev, 17.2 kev and 20.2 kev. Weber and van den Berge (Weber 1969) described the importance of coherent Rayleigh scattering as well as Compton scattering for phantom materials.

Griffith (Griffith 1978) adopted a formulation for Livermore phantom lungs which consisted of a foamed polyurethane and CaCO_3 . This formulation is identified as Griffith Lung in ICRU Report #44 (ICRU, 1989). The desired density and attenuation coefficient of the phantom lungs is achieved by carefully adjusting the quantity of polyurethane and CaCO_3 in the formulation. Mock lungs for plutonium calibrations should have a density range between 0.26 gm cm^3 and 0.30 gm cm^{-3} and a linear attenuation coefficient of 0.28 cm^{-1} at approximately 16 kev (ICRU, 1989).

An extensive series of interlaboratory comparisons were conducted in the United States and Europe to verify the performance of the original Livermore thoracic phantom. Each participating laboratory measured the phantom and compared their results to in vivo measurements of human volunteer subjects who inhaled short-lived radioactive materials which emit plutonium-like, low energy photons. Results of these intercomparison measurements confirmed the validity of the Livermore phantom for low energy photons (Griffith, 1978; Newton, 1978a; Newton, 1978b; Newton, 1984; Toohey, 1991). Newton claimed that use of the Livermore thoracic phantom would produce calibration factors correct to within 20 percent or better (Newton, 1984).

There have been a few modifications made to the original Livermore thoracic phantom since it was first produced in 1978. The contemporary commercial version of the Livermore Thoracic Phantom has a physical appearance similar to the original version but some of the original tissue substitute materials have been modified or replaced as the formulations supplied by manufacturers have been eliminated or changed. This is especially true for the foaming polyurethane used to produce the lungs. Changes in formulation were made to increase the working time of the material. (The original formulation of the two-part polyurethane foam produced a very rapid reaction after the components were mixed, typically allowing only 10 seconds to fill and seal the lung mold!) Another change in formulation was required when the original manufacturer of polyisocyanate, the basic raw material in the polyurethane, discontinued making the component formulation specified in the original Livermore procedure. Other, apparently benign physical changes in the phantom have been incorporated into the design, such as adding a neck and pelvic segment, which extends application of the phantom to more than just thoracic measurements.

Although several changes in design and materials for the phantom have been incorporated since its inception in 1978, no tests have been made to document that the technical performance of the contemporary calibration phantom meets the original design criteria for plutonium. Since it is unlikely that the original

international phantom validation will be repeated in the near future, and recognizing that substantial changes have been made in the lung phantom formulations, concern was raised about the contemporary version of the Livermore phantom, and whether it can achieve the same stringent performance criteria for low energy photons as established for the original phantom.

An informal, qualitative intercomparison was performed using one of the three original Livermore phantoms and a contemporary version of the thoracic phantom. The discrepancy in performance was thought to be associated with a change in the lung formulation materials. Resolution of this question led to a thorough investigation into the original formulations used to manufacture lungs for the Livermore phantom with the aim of reproducing the formulation using contemporary materials (Glover, 1992).

Recently, as part of the U. S. Department of Energy Laboratory Accreditation Program, KCl was added to the lung formulation so that K^{40} could be introduced as an interfering radionuclide similar to that encountered when a human subject is measured in vivo. Approximately 89.6 g of KCl (2.8 kBq) was required in the right lung and 70.4 g (2.2 K bq) in the left lung (MacLellan, 1988). Rather than making a permanent change in formulation for the Livermore phantom lungs, it was suggested that an alternative phantom be constructed especially for accreditation testing which would include KCl in the phantom shell thus avoiding the need to modify the original design

criteria for the Livermore lungs (Kramer, 1990). Distributing KCl throughout the phantom shell, rather than concentrating all the material in the lungs, should produce a smaller, albeit non-negligible, impact when performing calibrations for low energy photons. Any change in the original formulations for the Livermore phantom organs would likely introduce a change in their performance, especially when using radioactive standards which emit low energy photons. This is certainly true for the lungs which exhibit a very large change in attenuation coefficient whenever the formulation is modified even slightly.

OBJECTIVE

This paper will discuss the importance of the attenuation coefficient as a performance indicator for the phantom lungs and describe a destructive method for testing the attenuation coefficient of lungs fabricated at the University of Cincinnati (UC) using the original procedures developed by Livermore, but substituting contemporary materials having chemical formulations comparable to the original components. The UC lungs are fully compatible with the original³ chemical formulations for the Livermore phantom lungs and exhibit radiological characteristics

³The original formulations developed by Livermore for the lungs involved addition of 10 ml of acetone with a lanthanide nitrate carrier to insure uniform distribution of the radioactive isotope. Livermore determined that acetone and carrier were unnecessary and eliminated these components during fabrication of the original sets of lungs. The lung formulation used at the University of Cincinnati does not use the acetone and lanthanide carrier.

which are fully consistent with the original Livermore specifications. Even the formulation for the original epoxy sealant has been reproduced. It will also be shown what change is made to the attenuation coefficient when KCl is added to the formulation.

METHODS

The chemical formulation equivalent to the Livermore lung tissue substitute adopted by the University of Cincinnati (UC) was developed from the elemental composition of hydrogen, carbon, nitrogen, oxygen, magnesium, calcium, and tin listed for Griffith Lung in ICRU Publication #44 (ICRU, 1989). Raw materials, including polyurethane, calcium carbonate (CaCO_3), and catalyst, were selected for the UC formulation to produce a final reacted polyurethane having an elemental composition consistent with the Griffith Lung (Glover, 1992). Table 1 lists the elemental composition of the constituents of the UC lung tissue substitute. An extensive review of historical references, laboratory notebooks at Livermore National Laboratory, and discussions with suppliers of organic chemicals led to the identification of manufacturers willing to produce a series of contemporary products which duplicate the original specifications for the Livermore lungs and the epoxy sealant applied to the exterior surface of the lungs (Glover, 1992).

The mass attenuation coefficients for the lung formulations adopted by the University of Cincinnati were calculated using XCOM, a personal computer program for calculating photon cross-sections based upon the elemental composition of the materials used in the tissue substitute (Berger and Hubbell, 1987). The uncertainty in the mass attenuation coefficient calculated by XCOM for low-Z elements at low photon energies may range from 5% to 10% (ICRU, 1989). Using XCOM, it can be shown that lung tissue substitutes which incorporate elements having radiological characteristics dissimilar to those of the original Livermore specifications, are very likely to exhibit an attenuation coefficient substantially different than that of the original formulation.

Verification of the attenuation coefficient for the phantom lungs fabricated at the University of Cincinnati was accomplished by performing destructive measurements on several different samples of lungs. Measurements of the attenuation coefficient at 16.6 keV using a $\text{Nb}^{93\text{m}}$ source and uniformly thick samples cut from lungs demonstrate that the new materials are in excellent agreement with the original Livermore specifications as listed in ICRU Report #44 and calculated by XCOM. Measurement of the attenuation coefficient is a very sensitive test which can be used to predict the performance capabilities of a new lung tissue substitute material. Measurement of the attenuation coefficient will be shown to be an adequate predictor of the performance of

the lungs and also represents the best parameter for describing the quality of the lung phantom, especially when radionuclides involving low photon energy or X-rays are measured. Even the introduction of a small amount of an element with a high effective Z ($Z > 20$) will make a significant change in the attenuation coefficient since the photoelectric effect, which is the predominant mode of interaction at low energy, is very dependent upon the effective Z (actually, Z^4).

PROCEDURE

Several sets of lungs were fabricated at the University of Cincinnati for destructive analysis and measurement of the attenuation coefficient. Individual core samples, having a diameter of 6.25 cm each, were cut from three different lungs. Lung phantoms selected for this analysis were fabricated using identical procedures but at different times during the month to test whether there may be some unknown systematic bias in the procedure. In two of the lungs, replicate samples were obtained by withdrawing cores from different positions within the same lung. Measurement of the attenuation coefficient in samples from replicate cores of the same lung will determine whether there is any significant dependence of the attenuation coefficient with position inside the lung. Whenever possible, cores were cut in both parallel and perpendicular directions to the major axis of the lung. It will become obvious from the linear correlation of the results of the attenuation measurements that there is no

spatial dependence of the attenuation coefficient within the lung.

Cores from each lung were cut into uniform slices nearly equal in thickness. The thickness of each slice was measured at four different locations using a micrometer. These measurements were repeated by the same individual but on different days to confirm the original thickness results. The mean thickness and variance for each slice of the core was determined using a total of eight individual measurements.

Transmission measurements were performed using a $\text{Nb}^{93\text{m}}$ point source in a low radiation background shielded enclosure with 15.24 cm thick steel walls to minimize the contribution from background due to the natural radiation environment. A 3 mm thick, 5.08 cm diameter NaI(Tl) detector having a 5 mil thick beryllium entrance window was used to measure the transmission of the 16.6 keV (average) $\text{Nb}^{93\text{m}}$ x-rays through different layered slices of the lung core material. This energy closely resembles the x-ray energy emitted by plutonium and duplicates that used by Griffith during testing of the components used in fabrication of the original Livermore phantom (Griffith 1978). Although Griffith measured the transmission of the $\text{Nb}^{93\text{m}}$ x-rays in muscle and adipose tissue substitute materials, we found no reports in the literature or Livermore research notebooks which give results of attenuation measurements in the foaming polyurethane lung

substitute material.

Attenuation measurements performed with the UC lung substitute material used a detector configuration similar to that described by Griffith in which the source to detector distance was 14 cm (Griffith 1978). Figure 1 illustrates this geometrical arrangement. For the purposes of error analysis, the measurement results were assumed to follow a Poisson distribution. Each measurement was corrected for background.

RESULTS

The results of the attenuation measurements for Lung #49, Lung #46, and Lung #44 are shown on Table 2 and Table 3. The chemical formulation for Lung #44 was modified by the addition of 89.6 g of KCl, i.e., 2.8 K⁴⁰Bq. Although 89.6 g KCl is added to the formulation, only 81 g KCl will be in the lung since some KCl will remain with the residual materials after the lung mold is filled.

The source used in all measurements was a NIST Nb^{93m} point source (SRM 4267-30) having an activity of approximately 7.9×10^4 Bq. Results of replicate samples are given for Lung #44 and Lung #46 since both were the equivalent size of the right lung of Reference Man (ICRP, 1981) which made it possible to cut more than one core sample from each lung. It was not physically possible to obtain more than one core sample from Lung #49 since it was equivalent in size to the left human lung which is smaller

than the right lung. The errors reported with each measurement reflect the total propagated uncertainty in thickness and count rate.

The linear attenuation coefficient for each lung core sample was determined by performing a weighted least square regression of the count rate and sample thickness for several different values of sample thicknesses. Figure 2 illustrates the results of the linear regression obtained with Lung #46 (Core A) and Lung #44 (Core A). It is obvious from the slope of these curves that Lung #44, which contains 81 g KCl, has a significantly greater linear attenuation coefficient than Lung #46. Table 4 lists a summary of the linear attenuation coefficient for all five samples reported in this paper. The data on Table 4 indicate that the linear attenuation coefficient for Lung # 46 and Lung # 49 are within the recommended specifications for the original Livermore phantom. However, the addition of 89.6 g of KCl increased the linear attenuation coefficient at approximately 16 keV by nearly a factor of two compared to values for Griffith lung and human lung given in ICRU Report #44 (ICRU, 1989). The density for human lung, 0.26 gm cm^{-3} is used to convert the mass attenuation coefficient (μ/ρ) reported in ICRU Report #44 to values of linear attenuation coefficient measured in this work. The actual density of each lung phantom is a measured value.

DISCUSSION

The original design criteria established for the Livermore phantom was validated by an elaborate international intercomparison of measurement results performed with human volunteers who inhaled labelled Pd^{103} and whose lungs contained a known quantity of the radionuclide. Palladium-103 emits X-rays at 20.2 and 22.8 keV, somewhat higher in energy than plutonium. A second validation exercise was conducted using Nb^{92m} which emits Zr K X-rays at 15.8 and 17.7 keV as well as a 934 keV photon. Each of the participating laboratories also calibrated their detector systems using a set of Livermore lungs containing the radioactive material. The results of both these intercomparisons have demonstrated the suitability of the Livermore phantom as an adequate calibration device for low energy emitting radioactive materials deposited in the lungs (Newton 1984). Recent interests in extending the application of the Livermore phantom to calibrations at higher photon energies have led to the adoption of the Livermore phantom as a pseudo-standard for any radioactive material deposited in the lungs, liver, kidney, and GI tract. The commercial version of the phantom has removable internal organs to which most any radionuclide can be added.

Table 5 lists calculated values for the mass attenuation coefficient at photon energies between 1 keV and 100 keV for human lung tissue and the lung tissue substitute formulation developed at the University of Cincinnati. The mass attenuation coefficients listed on Table 5 were calculated using XCOM and the known elemental composition for the contemporary materials used

to fabricate Livermore-equivalent lungs at UC. The measured linear attenuation coefficient is easily converted to mass attenuation coefficient by dividing by the density of the phantom lung. Figure 3 shows how the calculated mass attenuation coefficient for human lung and the UC lungs vary with energy. The deviation of the lung containing KCl from the results for human lung is very apparent. Figure 4 shows the percent deviation of the calculated mass attenuation coefficient for each of the three lungs from that for human lung as reported in ICRU publication #44. Again, it is very apparent from the results shown in Figure 4 that KCl introduces a significant bias in the mass attenuation coefficient for the phantom lung and would likely produce a concomitant error in calibration measurements performed at low photon energies, especially for plutonium and Am²⁴¹.

An evaluation of the change in the attenuation coefficient of the phantom lungs with the addition of KCl was conducted to determine whether it was theoretically possible to introduce approximately 2 to 5 kBq of K⁴⁰ activity by altering any of the required components, especially the CaCO₃, to account for the KCl. XCOM was used to calculate the mass attenuation coefficient for the modified lung formulation. Figure 5 illustrates the percent deviation in the mass attenuation coefficient at different energies with increasing amounts of K⁴⁰ in the phantom lung. Even when the CaCO₃ is completely eliminated from the formulation, it is not possible to achieve

the appropriate mass attenuation coefficient with the desired K^{40} activity. The KCl introduces a very large percentage deviation in the mass attenuation coefficient from that obtained when phantom lungs are produced using the standard formulation and would introduce a significant performance bias if such lungs were used to calibrate for low energy photons.

It is obvious from the data reported in this paper that lungs used in the Livermore thoracic phantom to calibrate in vivo measurement system which monitor plutonium, americium, and uranium should be fabricated according to the original specifications adopted by Griffith (Griffith 1978). Since the linear attenuation coefficient measured with the UC Livermore equivalent lungs has been shown to be remarkably sensitive to even minor changes in the materials of fabrication, it is important not to alter these components. Commercial suppliers of calibration lungs which contain low energy, photon emitting radioactive materials should certify and document that the attenuation coefficient of their product meets the criteria specified for the original Livermore thoracic phantom. Use of lungs which have an attenuation coefficient which differs from the original specification will introduce a systematic error into the measurement results for low energy emitting radionuclides.

ACKNOWLEDGEMENT

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List of Figure Captions

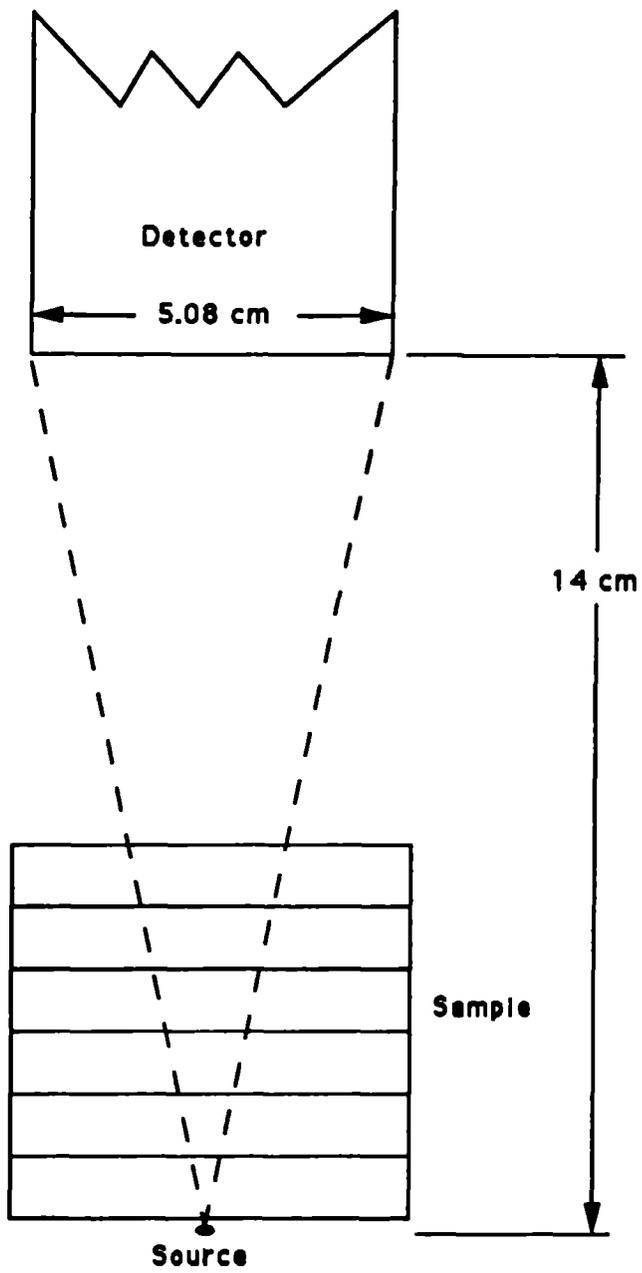
Figure 1: Geometrical arrangement of detector and standard source when measuring transmission of $\text{Nb}^{93\text{m}}$ X-rays through samples of lung tissue substitute material.

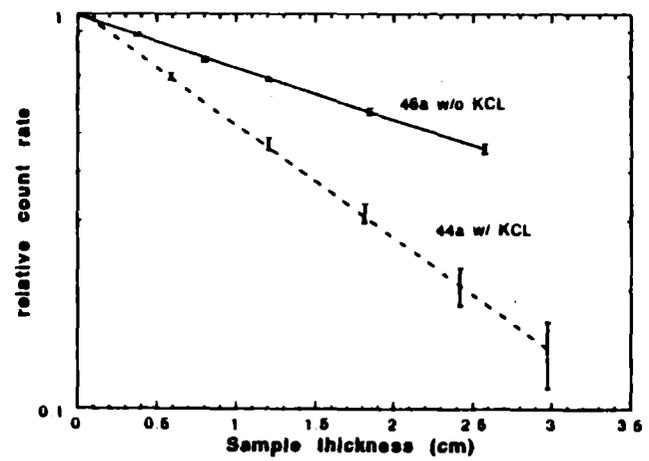
Figure 2: Transmission of $\text{Nb}^{93\text{m}}$ X-rays through samples of lung tissue substitute material. Sample #46a represents standard formulation described in text. Sample #44a contains KCl and represents a non-standard lung tissue substitute formulation.

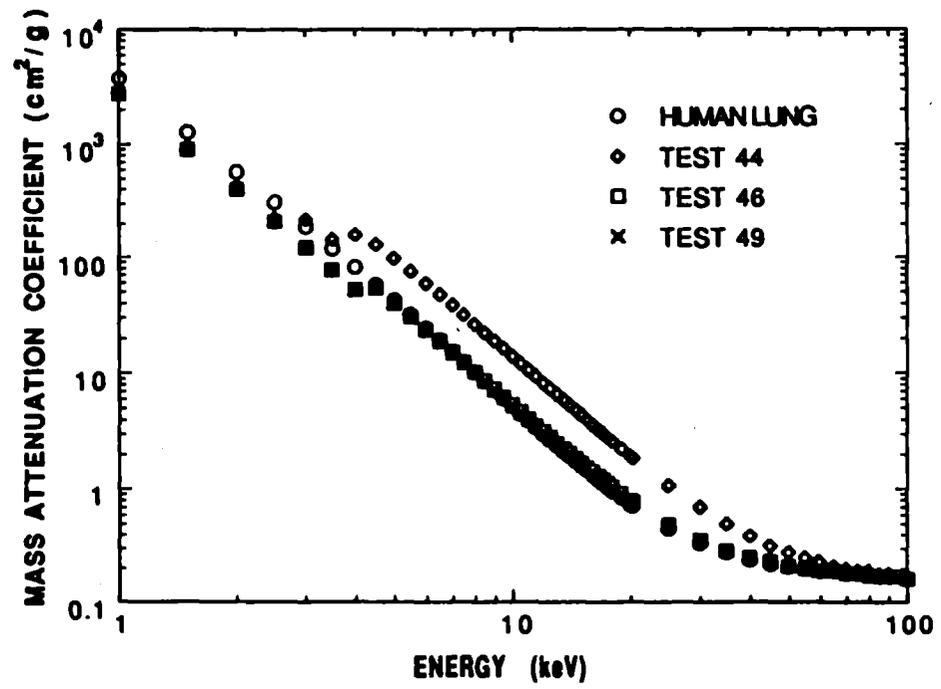
Figure 3: Comparison of the calculated mass attenuation coefficient for three phantom lungs and human lung. Sample # Test44, which includes 81 g of KCl, has a mass attenuation coefficient significantly greater than that for the other samples and human lung.

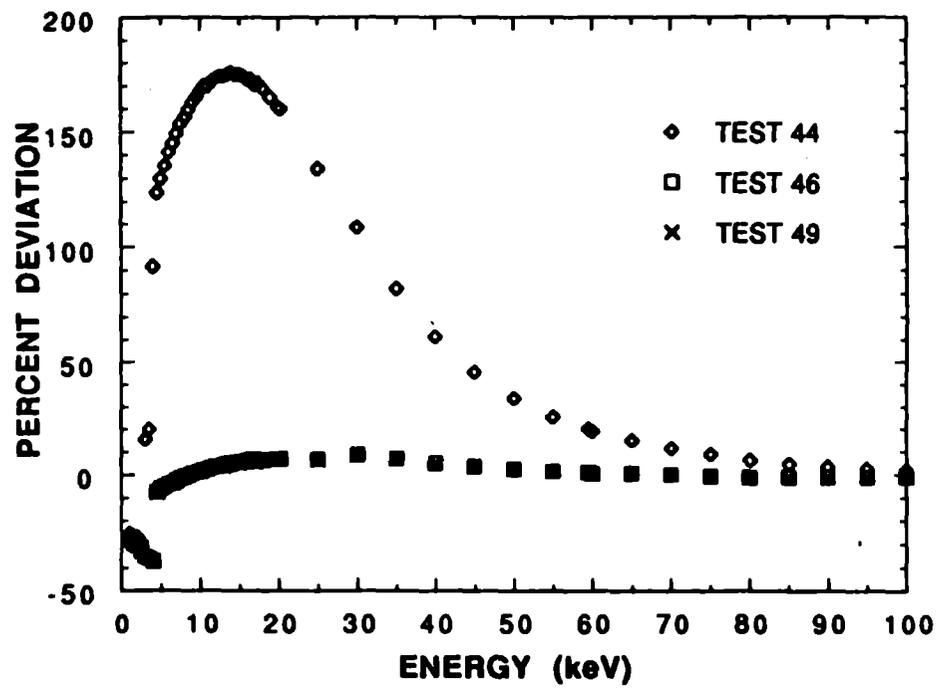
Figure 4: Percent deviation of the calculated mass attenuation coefficient relative to human lung. Sample # Test46, which was fabricated with 89.6 g KCl added to the standard formulation, has a mass attenuation coefficient nearly a factor of two greater than human lung between 10 keV and 20 keV, the energy region for plutonium X-rays. The standard formulation deviates little from human lung above 10 keV.

Figure 5: Calculated percent deviation in the mass attenuation coefficient from the original Livermore formulation due to the addition of KCl. Even with all CaCO_3 eliminated, it was not possible to achieve the mass attenuation coefficient equal to human lung in the plutonium X-ray region when KCl was added to the standard formulation.









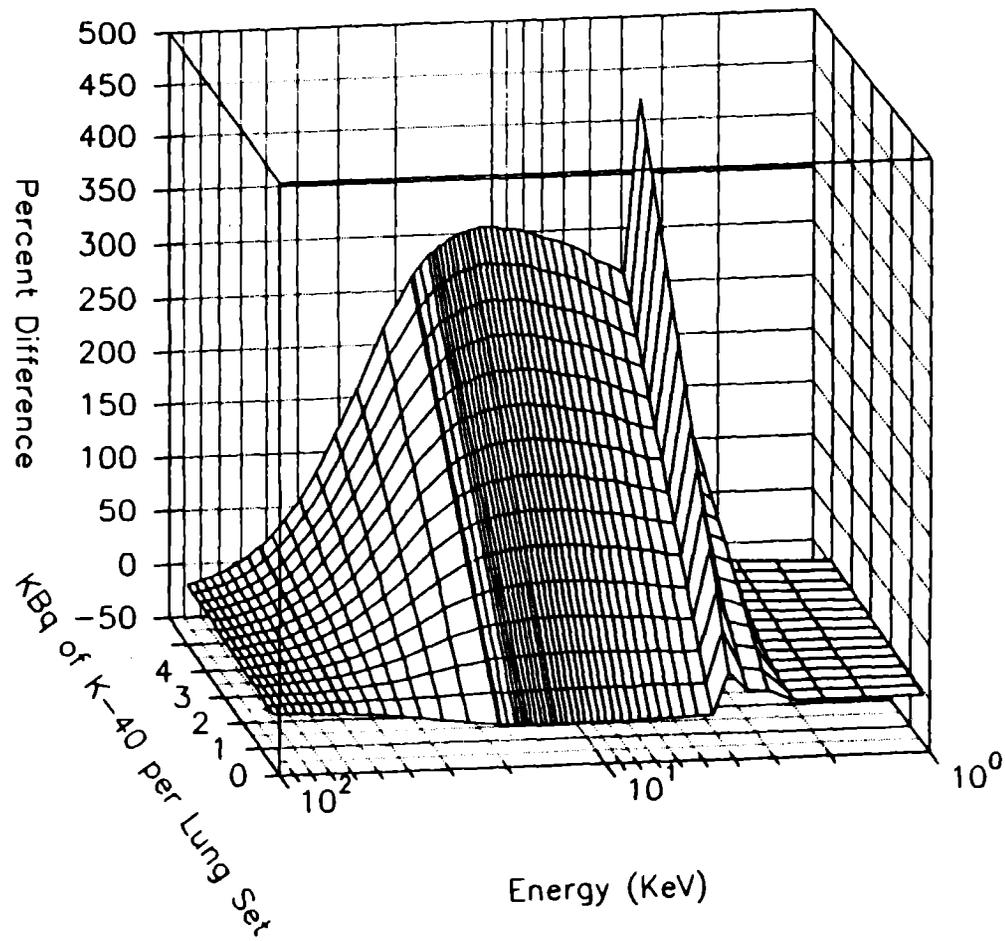


Table 1: Elemental composition of lung phantom materials (weight percent)

	H	C	N	O	Ca	Mg	Sn
Polyurethane	8.443	63.50	4.436	23.52	0	0.11	0
Calcium Carbonate	0	12.00	0	47.96	40.04	0	0
Catalyst	7.9	48.6	0.39	16.9	0	0	26.20

Table 2. Measurement of transmission of Nb93m x-rays through lung tissue substitute formulation.

Sample I.D.	Sample thickness (cm)	Net Count Rate (cpm)	relative count rate
44a	0	3473 ± 19	1 ± 0.007
	0.588 ± 0.017	2433 ± 16	0.701 ± 0.007
	1.207 ± 0.026	1638 ± 13	0.472 ± 0.006
	1.815 ± 0.026	1090 ± 11	0.314 ± 0.006
	2.418 ± 0.033	713 ± 9	0.205 ± 0.006
	2.974 ± 0.039	485 ± 7	0.140 ± 0.006
44b	0	3476 ± 19	1 ± 0.007
	0.590 ± 0.023	2306 ± 16	0.664 ± 0.007
	1.210 ± 0.026	1544 ± 13	0.444 ± 0.006
	1.833 ± 0.028	1037 ± 11	0.298 ± 0.006
	2.447 ± 0.040	727 ± 9	0.209 ± 0.006
	2.991 ± 0.043	455 ± 7	0.130 ± 0.006

Table 3. Measurement of transmission of Nb93m x-rays through lung tissue substitute material.

Sample I.D.	Sample thickness (cm)	Net Count Rate (cpm)	Relative Count Rate
46a	0	3487 ± 19	1 ± 0.007
	0.380 ± 0.010	3040 ± 18	0.889 ± 0.007
	0.806 ± 0.015	2688 ± 17	0.771 ± 0.007
	1.206 ± 0.017	2407 ± 16	0.690 ± 0.007
	1.851 ± 0.029	1996 ± 15	0.573 ± 0.006
	2.575 ± 0.037	1602 ± 13	0.460 ± 0.006
46b	0	3519 ± 19	1 ± 0.007
	0.506 ± 0.020	2968 ± 18	0.843 ± 0.007
	1.040 ± 0.042	2589 ± 17	0.736 ± 0.007
	1.628 ± 0.053	2130 ± 15	0.605 ± 0.006
	2.318 ± 0.077	1706 ± 13	0.485 ± 0.006
49	0	3488 ± 19	1 ± 0.007
	0.587 ± 0.019	2928 ± 18	0.840 ± 0.007
	1.085 ± 0.024	2514 ± 16	0.721 ± 0.006
	1.654 ± 0.027	2196 ± 15	0.630 ± 0.006
	2.233 ± 0.029	1859 ± 14	0.533 ± 0.006
	2.808 ± 0.032	1560 ± 13	0.447 ± 0.006
	3.380 ± 0.037	1314 ± 12	0.377 ± 0.006

Table 4: Linear attenuation coefficient measured in samples of phantom lungs

Sample I.D.	Linear Attenuation Coefficient* (cm⁻¹)
44a	0.652 ± 0.006
44b	0.662 ± 0.007
46a	0.301 ± 0.005
46b	0.308 ± 0.008
49	0.285 ± 0.003
Human Lung ^b	0.312

*16.6 keV average x-ray energy from Nb^{93m}

^bCalculated assuming a density of 0.26 gm cm⁻³

Table 5: Comparison of calculated mass attenuation coefficients for human lung and lung tissue substitute material

Calculated Mass Attenuation Coefficient Without Coherent Scatter (XCOM) (cm ² /g)					Percent Deviation of Mass Attenuation Coefficient Without Coherent Scatter (XCOM) from Human Lung (ICRU 44) (cm ² /g)				
Energy (keV)	Human Lung (ICRU 44)	TEST44	TEST46	TEST49	Energy (keV)	TEST44	TEST46	TEST49	
1.00	3800.00	2840.00	2740.00	2740.00	1.00	-25.26	-27.89	-27.89	
2.00	574.00	420.00	398.00	398.00	2.00	-26.83	-30.66	-30.66	
3.00	188.00	217.00	122.00	122.00	3.00	15.43	-35.11	-35.11	
4.00	82.40	158.00	51.80	51.70	4.00	91.75	-37.14	-37.26	
5.00	42.40	97.50	39.90	39.80	5.00	129.95	-5.90	-6.13	
6.00	24.50	59.10	23.50	23.50	6.00	141.22	-4.08	-4.08	
7.00	15.40	38.40	15.00	15.00	7.00	149.35	-2.60	-2.60	
8.00	10.30	26.40	10.20	10.20	8.00	156.31	-0.97	-0.97	
9.00	7.19	18.90	7.23	7.21	9.00	162.87	0.56	0.28	
10.00	5.23	14.00	5.31	5.30	10.00	167.69	1.53	1.34	
11.00	3.93	10.60	4.03	4.02	11.00	169.72	2.54	2.29	
11.50	3.44	9.36	3.54	3.54	11.50	172.09	2.91	2.91	
12.00	3.03	8.28	3.14	3.13	12.00	173.27	3.63	3.30	
13.00	2.40	6.58	2.50	2.49	13.00	174.17	4.17	3.75	
13.60	2.10	5.78	2.20	2.19	13.60	175.24	4.76	4.29	
14.00	1.93	5.32	2.03	2.02	14.00	175.65	5.18	4.66	
14.50	1.75	4.81	1.84	1.84	14.50	174.86	5.14	5.14	
15.00	1.59	4.37	1.68	1.67	15.00	174.84	5.66	5.03	
15.50	1.45	3.98	1.53	1.53	15.50	174.48	5.52	5.52	
16.00	1.33	3.63	1.41	1.40	16.00	172.93	6.02	5.26	
16.50	1.22	3.33	1.30	1.29	16.50	172.95	6.36	5.74	
16.60	1.20	3.27	1.28	1.27	16.60	172.50	6.67	5.83	
17.00	1.13	3.06	1.20	1.20	17.00	170.80	6.19	6.19	
17.06	1.12	3.03	1.19	1.18	17.06	170.54	6.25	5.36	
17.50	1.04	2.82	1.11	1.11	17.50	171.15	6.73	6.73	
18.00	0.97	2.61	1.03	1.03	18.00	169.07	6.19	6.19	
19.00	0.85	2.24	0.90	0.90	19.00	165.09	6.75	6.51	
20.00	0.74	1.94	0.80	0.80	20.00	160.75	6.99	6.85	
20.29	0.72	1.87	0.77	0.77	20.29	160.08	6.95	6.82	
25.00	0.46	1.07	0.49	0.49	25.00	134.14	6.78	6.56	
30.00	0.34	0.70	0.36	0.36	30.00	108.66	8.66	8.66	
40.00	0.24	0.39	0.25	0.25	40.00	61.16	4.96	4.96	
50.00	0.21	0.28	0.21	0.21	50.00	34.13	2.40	2.40	
59.54	0.19	0.23	0.19	0.19	59.54	20.31	1.04	1.04	
60.00	0.19	0.23	0.19	0.19	60.00	19.27	0.52	0.52	
70.00	0.18	0.20	0.18	0.18	70.00	11.54	0.00	0.00	
80.00	0.18	0.19	0.17	0.17	80.00	6.29	-1.14	-1.14	
90.00	0.17	0.18	0.17	0.17	90.00	3.55	-1.18	-1.18	
100.00	0.16	0.17	0.16	0.16	100.00	1.83	-1.22	-1.22	