UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

ATOMIC SAFETY AND LICENSING BOARD
Before Administrative Judges:
James P. Gleason, Chairman
Frederick J. Shon
Dr. Oscar H. Paris

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| In the Matter of ) | Docket Nos. |
| ) | |
| CONSOLIDATED EDISON COMPANY OF NEW YORK, ) | 50-247 SP |
| INC.   (Indian Point, Unit No. 2) ) | 50-286 SP |
| ) | |
| POWER AUTHORITY OF THE STATE OF NEW YORK ) | January 31, 1983 |
| (Indian Point, Unit No. 3) ) | |

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DIRECT TESTIMONY

of

DANIEL M. PISELLO, Ph.D.

and

RICHARD G. PICCIONI, Ph.D.

On Behalf Of

FRIENDS OF THE EARTH, INC.

and

NEW YORK CITY AUDUBON SOCIETY

## Qualifications of Dr. Daniel M. Pisello

Dr. Pisello is Assistant Professor of Physics at the New York Institute of Technology in New York City.  He graduated cum laude from Holy Cross College in 1964 with a B.S. in chemistry and received his doctorate in physics from Columbia University in 1976.  Dr. Pisello's dissertation was on "Inclusive Particle and Resonance Production in $\pi$+p Interaction."

He has served as Adjunct Assistant Professor of Physics at Columbia University (1977-1978), Fordham University (1979-1980), Hunter College (1979-1980), and Manhattan College (1980-1981).  He served as an Associate Research Scientist in experimental particle physics at New York University from 1976 to 1977.

He has been a Visiting Scientist at Yeshiva University and at the Institute of Theoretical Physics of the University of Naples, and is currently Director of Research for Accord Research and Educational Associates, Inc., in New York City.  His current research includes environmental radiation measurements, and studies in radiation epidemiology.

Dr. Pisello has published a book, Gravitation, Electromagnetism and Quantized Charge - The Einstein Insight, 1979, and articles in Physical Review Letters, Physics Letters, Physical Review, International Journal of Theoretical Physics, and Nuovo Cimento.  In addition his published articles include: "Critical Comment on the Cleanup at TMI," The Ecologist, 11, 1981 (with J. Harvey and R. Piccioni); "Strontium-90 Released in TMI Venting," Sicherheit in Chemie und Umwelt, 2, 1982 (with J. Harvey and R. Piccioni); and "The Zirconium Connection," The Ecologist, 4/5, 1979.

Dr. Pisello is a member of the American Physical Society, the American Association for the Advancement of Science, and Sigma Xi, the Scientific Research Society. His curriculum vitae is attached as an exhibit to this testimony.

## Qualifications of Dr. Richard G. Piccioni

Dr. Piccioni is Assistant Professor in the Department of Biological Sciences at Hunter College of the City University of New York. He graduated from the University of California at Irvine in 1972 with a B.S. in biology and a minor in chemistry. He received his doctorate in biophysics from Rockefeller University in 1977. Dr. Piccioni's dissertation was on "Calcium and Photosynthetic Oxygen Evolution in Blue-Green Algae." From 1977 to 1980 he was a Postdoctoral Fellow at Rockefeller University in the Laboratory of Biophysics and the Department of Cell Biology, where he conducted research into the biochemistry and biophysics of photosynthesis. His current research activities are exclusively in the field of radiation biology. In particular, he is engaged in laboratory research on the toxicity of Auger electron-emitting radionuclides in vitro, field monitoring of nuclear facilities, and epidemiological expressions of radiation exposure in utero.

Dr. Piccioni has published articles in Biochimica et Biophysica Acta, the European Journal of Biochemistry, G. Akoyunoglou, et al., eds., 1978, Oxygen and Living Processes, D. Gilbert, ed., 1981, and Methods in Chloroplast Molecular Biology, M. Edelman, et al., eds., 1982. In addition, his published articles include: "Critical Comment on the Cleanup at TMI," The Ecologist, 11, 1981 (with J. Harvey and D. Pisello); and "Strontium-90 Released in TMI Venting," Sicherheit in Chemie und Umwelt, 2, 1982 (with J. Harvey and D. Pisello). His curriculum vitae is attached as an exhibit to this testimony.

We present several possible scenarios involving substantial release of radionuclides from one of the nuclear reactors at the Indian Point Nuclear Generating Station in Buchanan, New York. Although scenarios with more severe consequences are possible, those presented here illustrate some implications of long-term environmental contamination following a serious reactor accident. The prevention of large numbers of excess cancers and other possible health effects among the potentially exposed population may require the relocation of large numbers of people, the interdiction of large areas of land for agricultural purposes, and interdiction for several years of major sources of drinking water for New York City or other communities in the vicinity of Indian Point. Contamination in the immediate vicinity of the reactor following an accident may be severe enough that maintenance of the situation at the Indian Point site, including tending to the damaged reactor, the undamaged reactor, and the spent fuel storage facilities would be impossible without exposing personnel to lethal doses of radiation.

All accident scenarios presented here are based on a PWR 2 type release from the Indian Point Unit 3 reactor (Appendix I). In each case surface deposition is calculated using a simple wedge model (Appendix II).

## Scenario 1.

The first scenario we consider is one in which the release occurs during an extended period of calm, or light variable winds.  (Wedge model parameters: $v_d$=.01 m/s; u=1 m/s; $\theta$=2$\pi$; H=100m.)  The dose rate at various distances from the damaged reactor due to deposited gamma emitters was calculated at various time intervals after the accident (Appendix III). One day after the release the dose rate one hundred meters from the release point is 235 rems per hour.  At this dose rate, a worker spending two hours on the plant site has more than a 50% chance of dying from radiation exposure within 30 days.  One week after the accident the dose rate at 100 meters is 100 rems per hour and one month after the release it is 28 rems per hour.  One year after the release the 100 meter dose rate is still 7.5 rems per hour, and even after 50 years the 100 meter dose rate is 5 rems per day, the maximum occupation exposure allowed for one year.

The dose rates in the early stages immediately after the accident are sufficiently high that the maintenance of the facilities on the site would be impossible without causing severe radiation sickness followed by death within weeks in many cases.  The difficulty of maintaining adequate surveillance of the existing facilities at the plant site under these conditions increases the likelihood of the original accident moving into a second stage which could involve further releases from the damaged reactor, a major release from the second reactor or from one of the spent fuel pools.

Scenario 2.

The second scenario we consider is characterized by a moderate wind which carries the plume south to New York City.  (Wedge model parameters: $v_d$ = .01 m/s; u=3 m/s; $\Theta$ = 0.25; H = 800 m.)  We calculate the dose rate due to gamma emitters deposited on surfaces at a point near the center of the city.  One day after release the dose rate is 9.6 rems per day.  After one week it is 4.1 rems per day; after one month, it is 1.2 rems per day. At the end of a year it is still 310 mrems per day.  After 50 years the dose rate is 9 mrem per day, approximately 30 times pre-accident background rate.

If the number of people living and working in the path of the plume at distances greater than 10 miles from Indian Point (approximately 4 million) neither decreases nor increases following the release, then the total external gamma population dose delivered over time due to deposited Co-58, Co-60, Zr-95, Ru-103, Ru-106, Te-127m, Te-132, I-131, Cs-134, Cs-137, Ce-141, and Ce-144 is 2.7 billion person-rems.  (The population density given in the IPPSS, Ref. 5, for a 22.5° sector centered due south was used.)  This population dose leads to an estimated 1.3 million extra cancer fatalities. The whole body population dose acquired over time due to inhalation of resuspended Sr-90, Pu-238, Pu-239, Pu-240, Pu-241, Am-241, Cm-242, Cm-244, Cs-137, and Cs-134 is estimated at 50 million person-rems, leading to an esti-mated 25,000 additional cancer fatalities (Appendix IV).  Appendix VII presents a discussion of the full range of dose-effect factors for fatal cancer induc-tion which appear in the scientific literature, and an explanation of our

choice of 2000 person-rem for the value of the whole body cancer dose used
to obtain the above cancer fatality predictions.

## Scenario 3.

A third scenario considers the plume moving northwest over the New York
City water supply Catskill catchment area, which provides 80% of New York City's
drinking water.  There a rainstorm washes out a substantial fraction of the
contents of the radioactive cloud.  One hour of rain under unstable atmospheric
conditions can lead to 97% depletion and deposition of the cloud contents.
An empirical relationship between deposition and concentration of strontium-90
in New York City tap water (Appendix V) predicts that deposition of 97% of
the cloud contents (approximately 50% of the release) into the Catskill catch-
ment area could result in concentration of strontium-90 in New York City tap
water in excess of the MPC (maximum permissable concentration) for drinking
water for two and one-half years. (MPC for Sr-90 in drinking water is
$3 \times 10^{-7}$ $\mu$Ci/ml, 10CFR part 50, Appendix B, Table II.)

## Scenario 4.

A fourth scenario considers the plume moving in a direction which
keeps it over land for a considerable distance.  Using the same wedge model
parameters as in Scenario 2., we calculate the maximum distance at which
deposition of Sr-90 and Cs-137 is sufficient to require interdiction of
land for agricultural purposes.  This distance is found to be 480 km,
requiring interdiction of approximately 10,000 sq. mi.

Presuming deposition of all released radionuclides within the boundaries
of New York State, we calculate the total whole-body population dose to resi-
dents of the state, using transfer factors obtained empirically from observation
of the behavior of atomic weapons fallout.  We calculate a total population dose
due to Sr-90 of 104 million person rems, and due to Cs-137, 77 million person rems,
leading to 90,000 fatal cancers (Appendix VI).

In the case of a plume like that discussed in Scenario 2, 72% of the
deposited radioactivity, and hence, contaminated agricultural land, would lie
outside a 50 mile radius of the plant, the usual limit of the Ingestion
EPZ (Emergency Planning Zone).  Therefore, 72% of the population dose and
cancer mortality calculated above would be undiminished by mitigative actions
proposed by the plant operators.

ADDENDUM ****

The following important result obtained by us after the submission
date is not part of this direct testimony.  The calculation of popula-
tion ingestion dose given above in Scenario 4 did not take into account
the large quantity of food produced in New York State for export.  Using
production figures for 1981 available from the New York Crop Reporting
Service the total ingestion of strontium-90 and cesium-137 was estimated
to be 77 times the value previously calculated.  The total population
dose from ingestion therefore increased to $1.4 \times 10^{10}$ person-rems (dose
commitment factors taken from Ref. 10) or $2.3 \times 10^{9}$ person-rems (dose
commitment factors taken from Ref. 1).  The bulk of this ingestion dose
comes from fruits and vegetables grown in New York State and consumed
out of state.  Less than 1% of the total population dose is due to
consumption of milk and dairy products.  Using the dose effect factor
of 2,000 person-rems per fatal cancer one obtains either 7 million of
1.2 million excess cancer fatalities due to ingestion of strontium-90
and cesium-137 depending on which dose conversion factors are used.

# APPENDIX I

## Released Radioactivity

The PWR 2 accident category is defined as follows:[1]

"This category is associated with the failure of core-cooling
systems and core melting concurrent with the failure of con-
tainment spray and heat-removal systems. Failure of the con-
tainment barrier would occur through overpressure, causing a
substantial fraction of the containment atmosphere to be
released in a puff over a period of about 30 minutes. Due to
the sweeping action of gases generated during containment
vessel meltthrough, the release of radioactive material would
continue at a relatively low rate thereafter. The total
release would contain approximately 70% of the iodines and
50% of the alkali metals present in the core at the time of
release. As in PWR release category 1, the high temperature
and pressure within containment at the time of containment
failure would result in a relatively high release rate of
sensible energy from the containment."

The following parameters are associated with a PWR 2 release:[2]

| | |
|---|---|
| Time of release | 2.5 hr |
| Duration of release | 0.5 hr |
| Elevation of release | 0 |
| Energy release | $170 \times 10^6$ Btu/hr |

### Fraction of Core Inventory Released

| Xe-Kr | I | Cs-Rb | Te-Sb | Ba-Sr | Ru[a] | La[b] |
|---|---|---|---|---|---|---|
| 0.9 | 0.7 | 0.5 | 0.3 | 0.06 | 0.02 | 0.004 |

(a) Includes Ru, Rh, Co, Mo, Tc
(b) Includes Y, La, Zr, Nb, Ce, Pr, Nd, Np, Pu, Am, Cm

Table I-1 lists the inventory at shutdown for Indian Point 3 with an average
burnup for the three core regions of 880, 17,600, and 26,400 megawatt-days
per metric ton of uranium. The inventory is scaled down by a factor of
(3025/3200) from the inventory given in the Reactor Safety Study[3] to take
into account the power output of IP3. The amount of each isotope released
in the PWR 2 accident is listed in the second column. The third column
contains a factor which adjusts the release for higher overall average
burnup of 17,600 megawatt-days per metric ton.[4]

TABLE I-1   SOURCE TERMS FOR PWR 2 RELEASE FROM INDIAN POINT 3

| Radionuclide | Half-Life (days) | Core Inventory (MCi) | $Q_i$ Quantity Released (MCi) | Factor for Higher Burnup |
|---|---|---|---|---|
| Co-58 | 71.0 | .737 | .0147 | — |
| Co-60 | 1,920 | .274 | .00548 | — |
| Kr-85 | 3,950 | .529 | .476 | 1.07 |
| Rb-86 | 18.7 | .0246 | .0123 | — |
| Sr-89 | 52.1 | 88.9 | 5.33 | 1.17 |
| Sr-90 | 11,030 | 3.50 | .21 | 1.41 |
| Y-90 | 2.67 | 3.69 | .0148 | 1.33 |
| Y-91 | 59.0 | 113 | .452 | 1.17 |
| Zr-95 | 65.2 | 142 | .568 | 1.06 |
| Nb-95 | 35.0 | 142 | .568 | 1.06 |
| Mo-99 | 2.8 | 151 | 3.02 | — |
| Ru-103 | 39.5 | 104 | 2.08 | 0.91 |
| Ru-106 | 366 | 23.6 | .472 | 0.76 |
| Rh-105 | 1.5 | 46.3 | .926 | 1.18 |
| Te-127m | 109 | 1.04 | .0936 | — |
| Te-131m | 1.25 | 12.3 | 3.69 | 1.15 |
| Te-132 | 3.25 | 113 | 33.9 | 1.00 |
| Sb-127 | 3.88 | 5.77 | 1.73 | — |
| I-131 | 8.05 | 80.4 | 56.3 | 1.00 |
| Xe-133 | 5.28 | 161 | 145 | 1.00 |
| Cs-134 | 750 | 7.09 | 3.54 | 0.14 |
| Cs-136 | 13.0 | 2.84 | 1.42 | 2.00 |
| Cs-137 | 11,000 | 4.44 | 2.22 | 1.23 |
| Ba-140 | 12.8 | 151 | 9.06 | 1.00 |
| La-140 | 1.67 | 151 | .604 | 1.00 |
| Ce-141 | 32.3 | 142 | .568 | 1.06 |
| Ce-143 | 1.38 | 123 | .492 | 1.15 |
| Ce-144 | 284 | 80.4 | .322 | 1.29 |
| Pr-143 | 13.7 | 123 | .492 | 1.15 |
| Nd-147 | 11.1 | 56.7 | .227 | 1.00 |
| Np-239 | 2.35 | 1550 | 6.2 | — |
| Pu-238 | 32,500 | .0539 | .00022 | 1.75 |
| Pu-239 | $8.9 \times 10^6$ | .0199 | $8.0 \times 10^{-5}$ | — |
| Pu-240 | $2.4 \times 10^6$ | .0199 | $8.0 \times 10^{-5}$ | — |
| Pu-241 | 5,350 | 3.21 | .0128 | — |
| Am-241 | $1.5 \times 10^5$ | .00161 | $6.4 \times 10^{-6}$ | — |
| Cm-242 | 163 | .473 | .0019 | — |
| Cm-244 | 6,630 | .0217 | $8.7 \times 10^{-5}$ | — |

FOOTNOTES

1.  Ref. 1, Appendix VI, page 2-2.
2.  Ref. 1, Appendix VI, Table VI 2-1, page 2-5.
3.  Ref. 1, Appendix VI, Table VI 3-1, page 3-3.
4.  Ref. 2, Appendix II, Table XXXIV, page S96.

APPENDIX II

Surface Deposition of Released Radioactivity

The area density of the $i^{th}$ radionuclide deposited on surfaces in the path of the plume in the absence of rain is given by the wedge model:[1]

$$\sigma_i(r,t) = Q_i G(r) \exp(-\lambda_i t)$$

where $G(r) = \lambda_d (r\theta)^{-1} \exp(-\lambda_d r)$ with $\lambda_d = v_d (uH)^{-1}$ and

   $r$ is the distance downwind from the release point
   $t$ is the time elapsed since release
   $Q_i$ is the quantity of the $i^{th}$ radionuclide released
   $H$ is the mixing height
   $u$ is the wind speed
   $\theta$ is the angular width of the plume
   $v_d$ is the deposition velocity and
   $\lambda_i^d$ is the radiological decay constant for the $i^{th}$ radionuclide.

The mixing height is defined as the height above the surface through which vigorous vertical mixing occurs.[2] Average morning and afternoon mixing heights observed at JFK during 1960-1964 under conditions of no precipitation are given here:[3]

### Average Mixing Heights in Meters

|           | Winter | Spring | Summer | Fall | Annual |
|-----------|--------|--------|--------|------|--------|
| Morning   | 875    | 788    | 662    | 675  | 750    |
| Afternoon | 901    | 1360   | 1512   | 1086 | 1214   |

Inversions, or isothermal conditions based below 500 feet occur approximately 25% of the time in the area of Indian Point and greater New York.[4]

Average wind speeds observed at JFK for the years 1960-1964 are:[5]

### Average Wind Speeds in Meters Per Second

|           | Winter | Spring | Summer | Fall | Annual |
|-----------|--------|--------|--------|------|--------|
| Morning   | 8.3    | 6.9    | 5.5    | 6.6  | 6.8    |
| Afternoon | 8.2    | 8.7    | 6.8    | 7.4  | 7.8    |

At Indian Point from 8/1/78 to 7/31/79 the wind has been observed from the north approximately 11% of the time with wind speeds corresponding to atmospheric stability classes A-G ranging from 1.1 m/s to 2.4 m/s at the 122 meter elevation.[6]

The angular width of the plume depends on the lateral dispersion which in turn depends on the atmospheric stability class. The angular width $\theta$ has been estimated for stability classes A-F using the formula:

$$\theta = \frac{4\sigma_y}{r}$$

where $\sigma_y$ is the horizontal dispersion parameter for a simple Gaussian dispersion model evaluated at r = 60 km.[7] The angular width obtained ranges from .36 radians for stability class A to .087 radians for class F.

The dry deposition velocity has a range of possible values from $10^{-3}$ m/s to $10^{-1}$ m/s.[8]

Wet deposition.

Depletion due to precipitation scavenging is given by exp $(-\Lambda t)$ where $\Lambda$ is the removal rate and t is the duration of precipitation. The fraction of airborne radioactivity brought down by precipitation is 1-exp $(-\Lambda t)$. The wet removal rate has a minimum expected value of $10^{-5}$ $s^{-1}$ and a maximum expected value of $10^{-2}$ $s^{-1}$; it has an average expected value under stable conditions (warm frontal storm) of $10^{-4}$ $s^{-1}$, and under unstable conditions (convective storm) a value of $10^{-3}$ $s^{-1}$.[9]

FOOTNOTES

1. Ref. 2, Appendix 2, page S97
2. Ref. 3, page 3.
3. Ref. 3, Table B-1, page 111.
4. Ref. 4, Figure 2.22, page 38.
5. Ref. 3, Table B-1, page 111.
6. Ref. 5, Tables 6.2-3A through 3G, pages 6.2-16 through 6.2-19.
7. Ref. 9, Figure 3-2, page 8.
8. Ref. 1, Appendix VI, page 6-2 and Table VI B-1, page B-9.
9. Ref. 1, Appendix VI, page 6-2 and Table VI B-1, page B-9.

# APPENDIX III

## External Gamma Dose

Whole body external gamma dose rate is given by:

$$R(t) = \sum_i D_i Q_i \exp(-\lambda_i t) G(r) f(t)$$

where r is the distance downwind from the release point, t is the time elapsed since the release, $D_i$ is the whole body external gamma dose rate per unit surface deposition of the $i^{th}$ radionuclide assuming uniform distribution on level ground, $Q_i$ is the quantity of $i^{th}$ radionuclide released, G(r) is defined in Appendix II, and f(t) represents the reduction of dose rate due to movement of radionuclides into the soil given by: [1]

$$f(t) = 0.63\exp(-1.13t) + 0.37\exp(-0.0075t)$$

Dose rate factors $D_i$ are derived from one day time-integrated dose factors $D_i^*$ given in the reactor safety study,[2] using:

$$D_i = D_i^* \lambda_i (1-\exp-\lambda_i)$$

Integrated doses are obtained by integrating R(t) over time.

The total external gamma population dose delivered to people continuing to reside in the path of the plume is calculated according to:

$$PD_{ext} = \int_0^\infty \int_{r_0}^{50mi} dt\, dr\, d\Theta\, r\, P(r) R(r,t)$$

where R(r,t) is the whole body external gamma dose rate given above, and P(r) is the population density as a function of distance from the reactor, assumed constant across the width of the plume and not changing in time. The lower limit $r_0$ is the radius outside of which no evacuation occurred. The upper limit of 50 miles is arbitrary. This integral factors according to:

$$PD_{ext} = [\lambda_d \sum Q_i D_i \int_0^\infty f(t)\exp(-\lambda_i t)dt]\,[\int_{r_0}^{50mi} P(r)\exp(-\lambda_d r)dr]$$

Population data from the Indian Point Probabilistic Safety Study were used to approximate the integral over space.[3]

III-1

FOOTNOTES

1.  Ref. 1, Appendix VI, Appendix E, page E-4.
2.  Ref. 1, Appendix VI, Appendix C, Table VI C-2, page C-6.
3.  Ref. 5, Table 6.2-5, page 6.2-24-26.

## Inhalation Dose Due to Resuspension

The total whole body population dose delivered to people continuing to reside in the path of the plume due to inhalation of resuspended particulates is calculated according to:

$$PD_{inh} = B \int_0^\infty \int_{r_0}^{50 \text{ mi}} dt \, dr \, d\theta \; rP(r) \; G(r) \sum_i Q_i I_i K(t) \exp(-\lambda_i t)$$

where $I_i$ is the fifty year inhalation dose committment factor for the ith radionuclide,[1] B is the average breathing rate,[2] and K(t) is the resuspension factor given by:[3]

$$K(t) = K_o \exp(-\lambda t) + K_e$$

with $K_o = 10^{-5} m^{-1}$; $K_e = 10^{-9} m^{-1}$; $\lambda = 0.677 \text{ yr}^{-1}$.

The double integral factors under the same assumptions made in Appendix III, according to :

$$PD_{inh} = [B \lambda_d \sum_i Q_i I_i \int_0^\infty dt \, f(t) \, \exp(-\lambda_i t)] \int_{r_0}^{50 \text{ mi}} dr \, P(r) \exp(-\lambda_d r)$$

Population data from the Indian Point Probabilistic Safety Study were used to approximate the integral over space.[4]

FOOTNOTES:

1. Ref. 11, Table 8, pages 36-39.
2. Ref. 11, Table B-4, page B-4. The adult value, 7300 $m^3$/y was used.
3. Ref. 1, Appendix VI, Appensic E, pages E-13.
4. Ref. 5, Table 6.2-5, page 6.2-24 through 26.

Model Relating Deposition of Strontium-90
to Concentration in N.Y.C. Water Supply

In order to calculate the effect of an impulse deposition at t=0 of S Curies
of Sr-90 in the N.Y.C. Watershed area on N.Y.C. tapwater, we assume the
occurrence of a maximum concentration of $C_o$ at time $t_d$ after deposition,
and an exponential decay of the concentration after this time. The
concentration C at any time after the impulse is given by:

$$C = \theta(t-t_d)C_o \exp[-\lambda(t-t_d)]$$

and the maximum concentration is given by:

$$C_o = fS$$

The parameters f and $\lambda$ were determined from fallout data.[1]

$$f = 4.87 \times 10^{-3} \ (pCi/l)/Ci$$

$$\lambda = .200y^{-1}$$

FOOTNOTES
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1. Ref. 6, Appendix A, pages A73-75; Ref. 8, Appendix D, page D5.

## APPENDIX VI

### Agricultural Interdiction and Ingestion Dose

The maximum distance at which surface deposition of Sr-90 and Cs-137 exceeds land contamination thresholds[5] is determined by solving the following equation for r:

$$\frac{\sigma_{Cs-137}}{20 \ \mu Ci/m^2} + \frac{\sigma_{Sr-90}}{2 \ \mu Ci/m^2} = 1$$

The total whole body population dose delivered to persons in New York State who consume food produced in New York after deposition of the total release within the state is calculated according to:

$$PD_{ing} = Q_i \times TF_i \times D_i \times I_{ing,i} \times P_{NYS} \div A_{NYS}$$

where $Q_i$ is the quantity of the ith radionuclide released (and deposited), $TF_i$ is the transfer factor for radionuclide i from surface to diet, $D_i$ is the rate of dietary uptake of the stable analog of i, $I_{ing,i}$ is the ingestion dose committment factor for the ith radionuclide[1], and $P_{NYS}$ and $A_{NYS}$ are the population and total surface area of New York State, respectively[4].

We carry out this calculation for Sr-90 and Cs-137 only, as these radionuclides dominate, using the following values for the parameters above:

|        | $TF_i$[2]                       | $D_i$[3]   | $I_{ing,i}$                    |
|--------|---------------------------------|------------|--------------------------------|
| Sr-90  | 5.06 pCi-y/gCa per mCi/km$^2$   | 370 gCa/y  | $1.86 \times 10^{-3}$ mrem/pCi |
| Cs-137 | 2.42 pCi-y/gK  per mCi/km$^2$   | 1430 gK/y  | $7.14 \times 10^{-5}$ mrem/pCi |

FOOTNOTES:

1. Ref. 11, Table 4.
2. Sr-90: Ref. 8, p I-43, Table 5; Cs-137: Ref. 26, p 15, Table 4.
3. Sr-90: Ref. 8, p I-33, Table 1; Cs-137: yearly K intake obtained according to:

$$D_K = 1.6 \ gK/kg \ milk \times 200 \ kg \ milk/yr \div .227 \ milk \ K/ \ total \ K$$

using values obtained from Ref. 25, p 488 Ref. 8, p I-33, Table 1, and Ref. 26, p 15, Table 4, respectively.
4. Ref. 27, p 839.
5. Ref. 2, p S 103, Table XXXIX.

# APPENDIX VII

## Basis of Whole-body Cancer Dose Estimate

In calculating cancer deaths resulting from whole-body exposure, a value of 2,000 person-rems has been utilized. Table VII-1 presents a spectrum of such values from the recent scientific literature. In each case, the recommended methodology for calculation of excess cancer deaths was used, assuming doses in the range 0 to 50 rads.

The wide discrepancy in the values for radiation-induced fatal cancer dose results in large part from adoption or rejection of a linear dose/response relation in the exposure range considered. It is a viewpoint shared by a large portion of the scientific community that linearity of response down to very low doses cannot be excluded by the available data.[1] Uncertainty in the slope of the dose/response curve in the low-dose range has been widely discussed, with highly divergent opinions having been reached by the authors of the references cited in Table VII-1.

The value we have adopted lies between the extremes shown in Table VII but could be too high or too low by at least an order of magnitude.

The effects of partial-body irradiation, such as would be expected as a result of ingestion or inhalation of Sr-90, on the dose-effect relation discussed above are difficult to judge on the basis of existing data on humans. The uncertainty in the effects, e.g., of bone marrow exposure due to incorporated bone-seeking radioactivity, are likely contained within the wide limits of uncertainty set by Table VII.

Recent statistical evidence obtained by ourselves strongly suggests a high sensitivity of human fetus to some component of weapons fallout.[2] This evidence consists of a highly significant correlation between fetal death ratios and dietary fallout levels obtaining during the period of atmospheric bomb tests. Our studies are distinguished from previous research efforts in this area by virtue of our inclusion of early fetal deaths (gestational age less than 20 weeks) occurring in those regions of the contiguous United States maintaining a high quality of reporting of such deaths.

The possibility of high fetotoxicity of ingested or inhaled radioactivity could greatly enhance the risk of spontaneous abortion in exposed pregnant women.

FOOTNOTES

1. Refs. 15, 16, 21, 22.
2. Ref. 23.

TABLE VII. ESTIMATES OF WHOLE-BODY CANCER DOSE OF LOW-LET RADIATION FOR POPULATIONS OF MIXED AGES.

| Source | Fatal Cancer Dose in Person-rems |
|---|---|
| RSS(1975)  Dose rates below 1 rem/day; central estimate of cancer risk.[a] | 22,300 |
| BEIR(1980)  75 yr exposure at 1 rad/yr; linear quadratic model; absolute risk projection; 4,751 cancer deaths per million persons irradiated.[b] | 16,000 |
| ICRP(1977)  100 cancer deaths per million person-rads.[c] | 10,000 |
| RSS(1975)  Upper estimate of cancer risk; 121.6 cancer deaths per million person-rads.[d] | 8,200 |
| BEIR(1980)  75 yr exposure at 1 rad/yr; linear model; absolute risk projection; 11,250 cancer deaths per million persons irradiated.[b] | 6,700 |
| BEIR(1980)  75 yr exposure at 1 rad/yr linear-quadratic model; relative risk projection; 11,970 cancer deaths per million persons irradiated.[b] | 6,300 |
| Radford(1980)  Lower estimate of cancer incidence (260 and 550 per million person rads for males and females, respectively) averaged and converted to mortality (approximately one-half incidence).[e] | 5,600 |
| BEIR(1980)  75 yr exposure at 1 rad/yr; linear model; relative risk projection; 28,690 excess cancer deaths per million persons irradiated.[b] | 2,600 |
| Radford(1980)  Upper estimate of cancer incidence risk (880 and 1620 per million person rads for males and females, respectively) averaged and converted to mortality (approximately one-half incidence.[e] | 1,700 |
| Morgan(1981)  Two-fold increase in BEIR (1980) risk (linear model, relative risk projection)due to revision of shielding factors in Hiroshima and Nagasaki.[f] | 1,300 |
| Rotblat(1978)  800 cancer deaths per million person-rads.[g] | 1,250 |
| Gofman(1981)  Central estimate of cancer dose.[h] | 268 |
| Kneale et al.(1978)  Doubling dose for cancer mortality estimated as 33.7 rads for males divided by spontaneous cancer death rate of 0.198.[i] | 170 |

FOOTNOTES TO TABLE VII

a. Ref. 1, Appendix VI, page 9-33, Table VI 9-7.
b. Ref. 14, page 146, Table V-3.
c. Ref. 12.
d. Ref. 1, Appendix VI, page 9-34, Table 9-4.
e. Ref. 16, page 386.
f. Ref. 19.
g. Ref. 15, page 44.
h. Ref. 17, page 294.
i. Ref. 18, page 404, Ref. 24.

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Columbia University, New York, New York.
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    M.Ph. in <u>physics</u>, 1974.
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Scuola Internationale di Fisica, "Enrico Fermi", Varenna, Italy.
    Summer session in <u>particle physics</u>, 1967.

Holy Cross College, Worcester, Massachusetts.
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    Manhattan College, Department of Physics, New York, New York  1980-1981.
    Pace University, Department of Chemistry and Physical Sciences, New York,
        New York.  Summer Session 1981.
    Fordham University, Department of Physics, New York, New York  1979-1980.
    Columbia University, Department of Physics, New York, New York, Science
        Honors Program, 1970, 1977-1978.
    New York University, Department of Physics, New York, New York  Summer
        Session 1977.


<u>PUBLICATIONS</u>

"The effect of weapons fallout on fetal mortality" abstract submitted for presenta-
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"Mobile monitoring of airborne radioactive effluent from the Oyster Creek Nuclear
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"Strontium-90 Released in T.M.I. Venting," Sicherheit in Chemie und Umwelt, <u>2</u> (1982)
    89-92, with J. Harvey and R.G. Piccioni.

PUBLICATIONS (continued)

"Critical Comment on the Cleanup at TMI," The Ecologist, 11 (1981) 138-142, with
    J. Harvey and R.G. Piccioni.

Gravitation, Electromagnatism and Quantized Charge - The Einstein Insight,
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"The Clue of the Hydrogen Bubble," In These Times, 3, 29, June 6-12, 1979.

"The Zirconium Connection," The Ecologist, 4/5, July-August 1979.

"Local Conserved Currents in Unified Field Theory," Nuovo Cimento, 48A, 184,
    November 1978, with R. de Ritis, D. Finkelstein, and D. Weil.

"Unified Field Theory with Homotopic Charge," International Journal of Theoretical
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"Meson Resonance Production in $\pi$+p Interactions at 15 GeV/c," Physics Review D,
    January 15, 1978, with C. Baltay, C.V. Cautis, D. Cohen, S. Csorna, M. Kalelkar,
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"Nonlinear Classical Theory of Electromagnetism," International Journal of
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"Distribution of Charge in $\pi$+p Interactions at 15 GeV/c," Physical Review D,
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"Search for Exotics Produced Opposite a Forward Lambda in $\pi$+p Interactions at
    15 GeV/c," Physics Letters, 57B, 293, July 1975, with C. Baltay, C.V. Cautis,
    D. Cohen, M. Kalelkar, W.D. Smith and N. Yeh.

"Search for Charmed Particle Production in 15 BeV/C $\pi$+p Interactions,"
    Physical Review Letters, 35, 1118, April 28, 1975, with C. Baltay, C.V. Cautis,
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RESEARCH POSITIONS

Director of Research, Accord Research and Education Associates, Inc. New York City,
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Visiting Scientist, in theoretical physics.
    University of Naples, Institute of Theoretical Physics, Naples, Italy. 1979.
    Yeshiva University, Department of Physics, New York City, New York. 1978.

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    New York University, Department of Physics, New York City, New York.
        High energy counter group, 1976-1977.
    Columbia University, Department of Physics, New York City, New York.
        Bubble Chamber group, 1974-1976.

## MEMBERSHIPS

American Physical Society

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## ADDITIONAL TEACHING

Astronomy.
    Adelphi University, ABLE Program, Urban Center, 1980.
    Mercy College, Ossining State Correctional Facility, 1980.

General science, elementary physics, chemistry and biology.
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    College of New Rochelle, School of New Resources, South Bronx, 1978.
    New York City Community College, 1974.

Elementary mathematics, college algebra.
    College of New Rochelle, School of New Resources, New York Theological Seminary, 1980.

Numerical analysis.
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Writing and problem solving.
    Adelphi University, ABLE program, Garden City campus, 1979.

Counselling and remediation.
    Richmond College Learning Center, Science and Mathematics Program, Staten Island,
    New York, 1974-1976.
    Director. Participated in design of academic skills center providing supplementary
    programs for upper division undergraduate students including peer tutoring, staff
    run workshops and academic counselling. Interviewed and evaluated prospective
    tutors. Provided academic and career counselling. Supervised tutors individually
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    aspects of tutoring. Observed tutors at work and experimented with video so that
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## PRESENT POSITION:

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## RESEARCH WORK EXPERIENCE:

May 1979               Postdoctoral Fellow, THE ROCKEFELLER UNIVERSITY,
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October 1980               Supervisor: Professor David C. Mauzerall
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## PUBLICATIONS:

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