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

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

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

DS03

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 π^+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; Θ = 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 rems 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 estimated 25,000 additional cancer fatalities. Appendix VII presents a discussion of the full range of dose-effect factors for fatal cancer induction 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 catchment 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 3×10^{-7} μCi/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 residents 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.

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 containment spray and heat-removal systems. Failure of the containment 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	170×10^6 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	$.00022_{-5}$	1.75
Pu-239	8.9×10^6	.0199	8.0×10^{-5}	-
Pu-240	2.4×10^6	.0199	8.0×10^{-5}	-
Pu-241	5,350	3.21	$.0128_{-6}$	-
Am-241	1.5×10^5	.00161	6.4×10^{-6}	-
Cm-242	163	.473	$.0019_{-5}$	-
Cm-244	6,630	.0217	8.7×10^{-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
θ is the angular width of the plume
v_d is the deposition velocity and
λ_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 θ has been estimated for stability classes A-F using the formula:

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

where σ_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 Λ 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:

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

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:

$$PD_{ext} = \int_0^{\infty} \int_{r_0}^{50mi} dtdrd\Theta rP(r)R(r,t)$$

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]

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.

APPENDIX IV

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:

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

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

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

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

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.

APPENDIX V

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 λ were determined from fallout data.[1]

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

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

FOOTNOTES

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:

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

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	1.86×10^{-3} mrem/pCi
Cs-137	2.42 pCi-y/gK per mCi/km^2	1430 gK/y	7.14×10^{-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; (upper estimate x 0.2).[a]	41,000
BEIR(1980) 75 yr exposure at 1 rad/yr; linear quadratic model; absolute risk projection; 4,751 cancer deaths per million persons irradiated.[b]	15,000
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]	6,100
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 9-36, 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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4. Meteorology and Atomic Energy 1968, David H. Slade, Editor, Air Resources Laboratories, U.S. Atomic Energy Commission Office of Information Services, July 1968.

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22. Pisello, D.M., R.G. Piccioni, G.P. McDaniel, "The effect of weapons fallout on fetal mortality," abstract submitted for presentation at May, 1983 AAAS Annual Meeting in Detroit, Michigan, January, 1983.

23. American Cancer Society "1979 Cancer facts and figures," New York, 1978.

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27. Webster's New Geographical Dictionary, G.C. Merriam Company, Springfield, MA, 1980.

DANIEL M. PISELLO, Ph.D.

EDUCATION

Columbia University, New York, New York.
Ph.D. in physics, 1976. Dissertation title: "Inclusive Particle and Resonance Production in π+p Interaction."
M.Ph. in physics, 1974.
M.S. in physics, 1970.

Scuola Internationale di Fisica, "Enrico Fermi", Varenna, Italy.
Summer session in particle physics, 1967.

Holy Cross College, Worcester, Massachusetts.
B.S., cum laude, in chemistry, 1964.

University of Vienna, Vienna, Austria.
Physical chemistry and theoretical physics, 1962-1963.

Cornell University, Ithaca, New York.
National Science Foundation summer institute in chemistry, 1959.

TEACHING POSITIONS (PHYSICS)

See page 3 for other teaching.

Assistant Professor of Physics.
New York Institute of Technology. Department of Physics, New York, New York 1982-present.

Assistant Professor of Physics.
New York Institute of Technology. Department of Physics, Old Westbury, New York 1981-1982.

Adjunct Assistant Professor of Physics.
Hunter College, Department of Physics, New York, New York 1979-1980.
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.

PUBLICATIONS

"The effect of weapons fallout on fetal mortality" abstract submitted for presentation at May 1983 AAAS Annual Meeting in Detroit, Michigan, January, 1983, with R.G. Piccioni and G.P. McDaniel.

"Mobile monitoring of airborne radioactive effluent from the Oyster Creek Nuclear Generating Station," submitted to International Perspectives in Public Health, December, 1982, with R.G. Piccioni.

"Strontium-90 Released in T.M.I. Venting," Sicherheit in Chemie und Umwelt, 2 (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, Ann Arbor Science Publishers, Inc., 1979.

"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 Physics, 17, 143, February 1978.

"Meson Resonance Production in π^+p Interactions at 15 GeV/c," Physics Review D, January 15, 1978, with C. Baltay, C.V. Cautis, D. Cohen, S. Csorna, M. Kalelkar, W.D. Smith and N. Yeh.

"Nonlinear Classical Theory of Electromagnetism," International Journal of Theoretical Physics, 16, 863, November 1977.

"Distribution of Charge in π^+p Interactions at 15 GeV/c," Physical Review D, June 1, 1976, with C. Baltay, C.V. Cautis, D. Cohen, M. Kalelkar, W.D. Smith and N. Yeh.

"Evidence for a New Meson Reonance at 2340 MeV," Physical Review Letters, 35, 891, October 1975, with C. Baltay, C.V. Cautis, D. Cohen, M. Kalelkar, W.D. Smith and N. Yeh.

"Search for Exotics Produced Opposite a Forward Lambda in π^+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 π^+p Interactions," Physical Review Letters, 35, 1118, April 28, 1975, with C. Baltay, C.V. Cautis, D. Cohen, S. Csorna, M. Kalelkar, E. Schmidt, W.D. Smith and N. Yeh.

RESEARCH POSITIONS

Director of Research, Accord Research and Education Associates, Inc. New York City, New York. 1979 -

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.

Associate Research Scientist, in experimental particle physics.
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

Sigma Xi, the Scientific Research Society.

ADDITIONAL TEACHING

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

General science, elementary physics, chemistry and biology.
Hunter College, 1981.
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.
New York Institute of Technology, Manhattan campus, 1981.

Natural science and human values, environmental issues and public policy, history of science.
Adelphi University, ABLE program, World Trade Center and Urban Center, 1979-1980.

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 and led weekly tutors' discussion group to develop technical and interpersonal aspects of tutoring. Observed tutors at work and experimented with video so that tutors could observe themselves. Conceived and supervised implementation of a student designed and operated computerized data storage and retrieval system to monitor the center's tutoring activities.

CURRICULUM VITAE

RICHARD G. PICCIONI

B.S. 1972 UNIVERSITY OF CALIFORNIA AT IRVINE
Major: Biology
Minor: Chemistry

Ph.D. 1977 THE ROCKEFELLER UNIVERSITY (Biophysics)
Supervisor: Professor David C. Mauzerall
Dissertation: "Calcium and photosynthetic oxygen evolution in blue-green algae."

PRESENT POSITION:

Since Oct. 1980 HUNTER COLLEGE, THE CITY UNIVERSITY OF NEW YORK, New York City. Department of Biological Sciences, Assistant Professor.
Actively conducting research on radiation biology of Auger-electron emitters, field monitoring of nuclear facilities, and epidemiological expression of radiation effects.

RESEARCH WORK EXPERIENCE:

May 1979 to October 1980 Postdoctoral Fellow, THE ROCKEFELLER UNIVERSITY, Laboratory of Biophysics.
Supervisor: Professor David C. Mauzerall
Field: Biochemistry and biophysics of photosynthesis
Support: National Institute of Health postdoctoral fellowship.

July 1977 to April 1979 Postdoctoral Fellow, THE ROCKEFELLER UNIVERSITY, Department of Cell Biology.
Supervisors: Dr. Nam-Hai Chua and Professor Phillip Siekevitz
Field: Biosynthesis of the photosynthetic apparatus.
Support: National Science Foundation/National Institutes of Health Postdoctoral Fellowships.

July 1972 to June 1977 Graduate Fellow, THE ROCKEFELLER UNIVERSITY, Department of Biophysics.
Supervisors: Professor David C. Mauzerall
Field: Biochemistry and biophysics of photosynthetic oxygen evolution.
Support: Rockefeller University Graduate Fellowship.

HONORS AND AWARDS:

Research support for the study of Intracellular Localization of Auger Electron Emitting Radionuclides, DEPARTMENT OF BIOLOGICAL SCIENCES/DIVISION OF SCIENCES AND MATHEMATICS, HUNTER COLLEGE OF THE CITY UNIVERSITY OF NEW YORK, 1982.

Research Grant, PROFESSIONAL STAFF CONGRESS, THE CITY UNIVERSITY OF NEW YORK, 1981.

Competitive Research Grant, UNITED STATES DEPARTMENT OF AGRICULTURE, 1980.

Postdoctoral Fellowship, NATIONAL INSTITUTES OF HEALTH, 1978.

Postdoctoral Fellowship, NATIONAL SCIENCE FOUNDATION, National Needs Program, 1977.

Undergraduate Summer Research Fellowship, NATIONAL SCIENCE FOUNDATION, 1971.

PUBLICATIONS:

Piccioni, R.G. and D.C. Mauzerall, "Increase effected by calcium ion in the rate of oxygen evolution from preparations of Phormidium luridum," Biochimica et Biophysica Acta, 723 (1976), 605-609.

Piccioni, R.G. and D.C. Mauzerall, "Calcium and photosynthetic oxygen evolution in cyanobacteria," Biochimica et Biophysica Acta, 504 (1978), 387-397.

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Bennoun, P., A. Masson, R. Piccioni, and N.-H. Chua, "Uniparental mutants of Chlamydamonas reinhardi defective in photosynthesis," in Chloroplast development, G. Akoyunoglou et al., eds., Elsevier/ North Holland Biomedical Press, 1978.

Piccioni, R.G., P. Bennoun, and N.-H. Chua, "A nuclear mutant of Chlamydamonas reinhardti defective in photosynthetic phosphorylation: Characterization of the algal coupling factor," European Journal of Biochemistry, 117 (1981), 93-102.

Mauzerall, D.C. and R.G. Piccioni, "Photosyntnetic oxygen production," Chapter 6 of Oxygen and living processes, D. Gilbert, ed., Springer-Verlag (1981).

Harvey, J., R.G. Piccioni, and D.M. Pisello, "Critical comment on the cleanup at T.M.I.," The Ecologist, 11 (1981) 138-142.

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Harvey, J., R.G. Piccioni, and D.M. Pisello, "Strontium released in T.M.I. venting," Sicherheit in Chemie und Umweit, 2 (1982) 89-92.

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