UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	
CAROLINA POWER & LIGHT COMPANY	)	Docket Nos. 50-400 OL
and NORTH CAROLINA EASTERN	)	50-401 OL
MUNICIPAL POWER AGENCY	)	
	)	
(Shearon Harris Nuclear Power	)	
Plant, Units 1 and 2)	)	

APPLICANTS' TESTIMONY OF JOHN J. MAURO
AND STEVEN A. SCHAFFER
ON JOINT CONTENTION II(e)
(FLY ASH)

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I. Introduction

My name is John J. Mauro. I am the Director of the Radiological Assessment and Health Physics Department of Envirosphere Company, a division of Ebasco Services, Inc. Ebasco is the architect-engineer for the Shearon Harris Nuclear Power Plant. As indicated in Attachment 1A to this testimony, I have a doctorate in biology and radiological health and am a certified health physicist. I have worked for the last twelve years in the field of radiological assessment, and have written a number of publications in this field.

My name is Steven A. Schaffer. I am Senior Radiological Assessment Engineer at Envirosphere Company. As indicated in Attachment 1B, I have a doctorate in biology and environmental health science. I have worked for the last ten years in the field of environmental assessment. I also have published in my field.

We have assisted Carolina Power & Light Company (CP&L) in the preparation of the radiological assessments contained in the Harris Plant Environmental Report (ER). We also have reviewed the Draft and Final Environmnental Statements (DES and FES) prepared by the NRC Staff which assess the environmental impact of operation of the Harris Plant.

The purpose of this testimony is to respond to part of Joint Contention II(e), which states:

The long term somatic and genetic health ef-
fects of radiation releases from the facility
during normal operations, even where such re-
leases are within existing guidelines, have
been seriously underestimated for the follow-
ing reasons ... e) the radionuclide concen-
tration models used by Applicants and the NRC
are inadequate because they underestimate or
exclude the following means of concentrating
radionuclides in the environment .... radio-
nuclides absorbed in or attached to fly ash
from coal plants which are in the air around
the SHNPP site.

A review of the pleadings on Contention II(e) reveals that
the contention may be interpreted as follows. The radio-
nuclides in the routine gaseous effluent from the Harris Plant
may become associated with fine airborne particles originating
from the combustion of fossil fuels. It is contended that once
bound to the particles, the radionuclides will behave differ-
ently than that assumed in the calculation performed by Appli-
cants and the NRC Staff and, as a consequence, result in doses
which are greater than those presented in the ER and the FES
for the Harris Plant.

More particularly, Contention II(e) is concerned with two
distinct issues. The first issue is whether doses calculated
via the inhalation route are underestimated because radio-
nuclide adsorption onto respirable fly ash in the ambient atmo-
sphere was not taken into account. It is contended that this
particle adsorption would cause more of the radionuclides in
the gaseous effluent to penetrate deeper into the lungs and be
retained for longer periods of time. The second issue is

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whether the doses from the radioactive gaseous emissions, calculated by Applicants and the NRC Staff for the crop-food-chain pathway, are underestimated because the calculations did not account for radionuclides bound to particles depositing more readily onto the ground, pasture and crops. It should be noted that these two concerns are not mutually exclusive. Increased radionuclide deposition on the ground due to particle adsorption decreases the quantity of radionuclides available to be inhaled. However, for simplicity and conservativism, we will neglect the inverse relationship between particle deposition rate and inhalation dose and deal with the two issues separately.

With regard to the first issue, Joint Intervenors are challenging the inhalation dose conversion factors tabulated in Regulatory Guide 1.109. With regard to the second issue, Joint Intervenors are challenging the deposition velocities assumed in Regulatory Guide 1.111. This testimony demonstrates that neither of the concerns identified in Joint Contention II(e) invalidates the dose calculations performed by Applicants and the NRC Staff.

II. Inhalation Dosimetry

In this portion of our testimony, we review the inhalation dose calculation methodology used by Applicants and the NRC Staff. First, we consider the significance of the phenomenon

of radionuclides attaching to fly ash. Detailed consideration is then given to the bases for the inhalation dose conversion factors because this is where the exposure model treats particle adsorption and subsequent lung deposition and retention. From this review, it will be seen that the assumptions used to develop the inhalation dose conversion factors account for the concerns raised by the Joint Intervenors. Next, we describe the nature of ambient atmospheric particles, especially coal combustion fly ash, and show that the calculational models properly account for the presence of these particles. Finally, we present two calculations of inhaled dose, first assuming radionuclide binding to very small particles and then assuming low solubility. They demonstrate that, notwithstanding these assumptions, the calculated doses from inhalation remain unchanged.

A.   Significance of Joint Contention II(e)
      for Inhaled Radionuclides

It is important to understand that the phenomenon of concern in Joint Contention II(e), namely, radionuclides attaching to fly ash in the atmosphere and then lodging in the lung, is only applicable to radionuclides that can take particulate form. This is because radionuclides that cannot take particulate form will not stay in the lung, but will be immediately exhaled or absorbed into the body fluids. Tritium is not

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in particulate form; it is inhaled as water vapor and, hence, that fraction not exhaled is immediately absorbed. Tritium makes up over 98 percent of the whole body dose from inhalation. See Table 1. Thus, the concern identified in Joint Contention II(e) only applies to the remaining two percent of the inhalation dose.

Notwithstanding the fact that the fly ash phenomenon of concern in Joint Contention II(e) can have little impact since it only affects a small fraction of the dose received by the public, this testimony considers whether the inhalation dose model used by Applicants and the NRC Staff adequately accounts for this phenomenon.

B.   Inhalation Dose Model

The calculational method used by both Applicants and the NRC Staff is in accord with Regulatory Guide 1.109. The calculation requires four pieces of information:

1)   the source term, expressed as curies per year (Ci/yr);

2)   the atmospheric dispersion factor at the location of the maximally exposed individual, expressed in units of curies per cubic meter (ci/m^3) at a point offsite, per curies released from the plant per second (Ci/sec);

TABLE 1

Inhalation Dose for the Harris
Plant, Based on Regulatory Guide 1.109*/

NUCLIDE	T.BODY	GI-TRACT	BONE	LIVER	KIDNEY	THYROID	LUNG	SKIN
H 3	7.44E-02 98.9%	7.44E-02 99.34%	0. 0.00%	7.44E-02 98.60%	7.44E-02 99.08%	7.44E-02 54.00%	7.44E-02 92.45%	7.44E-02 100.00%
I 131	8.81E-05 0.12%	2.70E-05 0.74%	1.08E-04 8.95%	1.54E-04 0.26%	2.64E-04 0.35%	5.13E-02 37.23%	0. 0.00%	0. 0.00%
I 133	2.54E-05 0.03%	4.98E-05 0.07%	4.85E-05 4.00%	8.30E-05 0.11%	1.45E-04 0.19%	1.21E-02 8.77%	0. 0.00%	0. 0.00%
MN 54	2.64E-05 0.70%	3.24E-05 0.04%	0. 0.00%	1.66E-05 0.02%	4.13E-06 0.00%	0. 0.00%	5.87E-04 0.73%	0. 0.00%
FE 59	1.45E-06 0.00%	2.57E-05 0.03%	1.61E-06 0.13%	3.80E-06 0.00%	0. 0.00%	0. 0.00%	1.39E-04 0.17%	0. 0.00%
CO 58	2.84E-06 0.00%	1.46E-04 0.19%	0. 0.00%	2.17E-06 0.00%	0. 0.00%	0. 0.00%	1.27E-03 1.58%	0. 0.00%
CO 60	2.63E-06 0.01%	1.85E-04 0.25%	0. 0.00%	7.49E-06 0.00%	0. 0.00%	0. 0.00%	3.88E-03 4.83%	0. 0.00%
SR 89	2.69E-07 0.00%	1.08E-05 0.01%	9.37E-06 0.77%	0. 0.00%	0. 0.00%	0. 0.00%	4.31E-05 0.05%	0. 0.00%
SR 90	3.39E-05 0.05%	4.01E-06 0.03%	5.52E-04 45.54%	0. 0.00%	0. 0.00%	0. 0.00%	5.34E-05 0.07%	0. 0.00%
CS134	3.05E-04 0.41%	4.36E-06 0.00%	1.56E-04 12.90%	3.56E-04 0.47%	1.20E-04 0.16%	0. 0.00%	4.09E-05 0.05%	0. 0.00%
CS137	3.00E-04 0.40%	5.90E-06 0.00%	3.36E-04 27.71%	4.36E-04 0.58%	1.56E-04 0.21%	0. 0.00%	5.28E-05 0.07%	0. 0.00%
TO.L.	7.51E-02	7.49E-02	1.21E-03	7.54E-02	7.51E-02	1.38E-01	8.04E-02	7.44E-02

Age Group = Adult   Location = 1.7 mi. NNE

* This Table relies on Revision 1 to Reg. Guide 1.109 (1977), whereas the ER relies on
  Revision 0 to Reg. Guide 1.109 (1976).

3) the inhalation rate of the maximally exposed individual expressed as cubic meters per second (m^3/sec); and

4) the inhalation dose conversion factor, expressed as millirem per picocurie (mrem/pCi) inhaled.

The product of these four terms, with appropriate unit conversion, yields the inhalation dose, as presented in the ER and the FES.

A discussion of the bases for the fourth factor, the inhalation dose conversion factor, is important because it is this factor which accounts for radionuclide lung deposition and clearance, which is the subject of Joint Contention II(e). The inhalation dose conversion factors used by Applicants and the NRC Staff are listed by radionuclide, organ and age group, in Tables C-1 through C-4 of Regulatory Guide 1.109. These values are expressed as the 50-year integrated dose commitment to the specified organ per unit of radionuclide activity inhaled (i.e., mrem/pCi).

In order to derive the dose conversion factor values, a two-compartment lung model was developed which simulates the behavior of radionuclides following inhalation. The model was first desscribed in ICRP-2 (1959). Upon inhalation of any material, the material is either immediately exhaled or it is deposited in two areas of the respiratory region (the upper and lower respiratory passages). Once deposited in the two

compartments of the respiratory system, the material is cleared at varying rates depending on the chemistry of the particle and the site of deposition. Once cleared from the lung, the material is translocated to other locations in the body and is eventually eliminated via radioactive decay and excretion. The dose conversion factors listed in Regulatory Guide 1.109 for inhalation reflect the time-integrated dose to each organ as the radionuclides are transported through the body following inhalation.

Deposition and retention of radionuclides in the lungs depend on many factors such as size, shape and density of the radioactive material, the chemical form and whether or not the person is a mouth-breather. At the time the lung model was developed, there was limited emperical data to determine the actual effects of particle size, shape and chemistry on lung deposition patterns. The model therefore makes assumptions about the deposition and clearance pattern of the inhaled radionuclides. Specifically, the model assumes that 75 percent of the inhaled material is deposited and 25 percent is immediately exhaled. Of the 75 percent deposited, 50 percent is deposited in the upper respiratory tract and 25 percent in the deep lung. The model also assumes that half of the insoluble particles deposited in the deep lung are removed in 24 hours, and half are retained with a half life of 120 days (ICRP-2). Soluble particles are assumed to pass through the lung.

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More recently, several studies using human subjects have measured particle deposition in the lung as a function of particle aerodynamic diameter. The term aerodynamic diameter refers to the diameter of a unit density sphere having the same terminal settling velocity as the particle under consideration. Terminal settling velocity is the equilibrium velocity of a particle that is falling under the influence of gravity and fluid resistance and is dependent upon particle size, shape and density.

A comparison of the experimental data and the assumptions in the lung model for percent deposition and distribution shows the model used to derive the dose conversion factors to be somewhat conservative. The percent particle deposition in the total respiratory system (upper and lower lung compartments) ranges from less than 10 to 100 percent of the total particles inhaled, depending upon particle size. (EPA 1982). However, the size of respirable fly ash particles in ambient atmospheres has a median aerodynamic diameter of about 2.0 micrometer (μm) (see next section). As indicated in the review by the EPA (EPA 1982), the deposition fraction for most particles in the size range of fly ash is about 30 percent but can approach 60 percent for sizes near the 2.0μm diameter. These fractions can be compared to the 75 percent fraction assumed in the model. Thus, the model assumes a greater quantity of particles of the size of fly ash is deposited in the total lung than has actually been observed to occur.

With respect to particle deposition in the deep lung, where long term retention can occur, the emperical data indicate that 10 to 30 percent of the inhaled particles in the size range of 0.1 to 2.0μm is deposited (Figure 1). This fraction is estimated to be less for nose-breathing (Figure 1). Comparing the measured deposition fraction (10 to 30 percent) to the fraction assumed in the model (25 percent), it can be seen that the model is reasonable, if not somewhat conservative, in its assumption of radionuclide deposition fraction in the deep lung. Therefore, the inhalation doses calculated by Applicants and the NRC have not been underestimated due to inappropriate lung deposition patterns.

Joint Contention II(e) focuses on the retention of particles in the lung. Particle retention in, as well as subsequent translocation from the lung is also dependent upon the solubility of inhaled material. The less soluble a radioactive particle, the greater dose it will deliver to the lung. Thus, soluble radionuclides are rapidly transported into the body which tends to reduce the lung dose, whereas insoluble radionuclides remain in the lung for a much longer time producing a greater dose to the lung and a much smaller dose to the rest of the body.

The inhalation dose conversion factors in Regulatory Guide 1.109 take into account lung retention based upon a solubility classification. Radioelements are classified as soluble or unsoluble as follows:
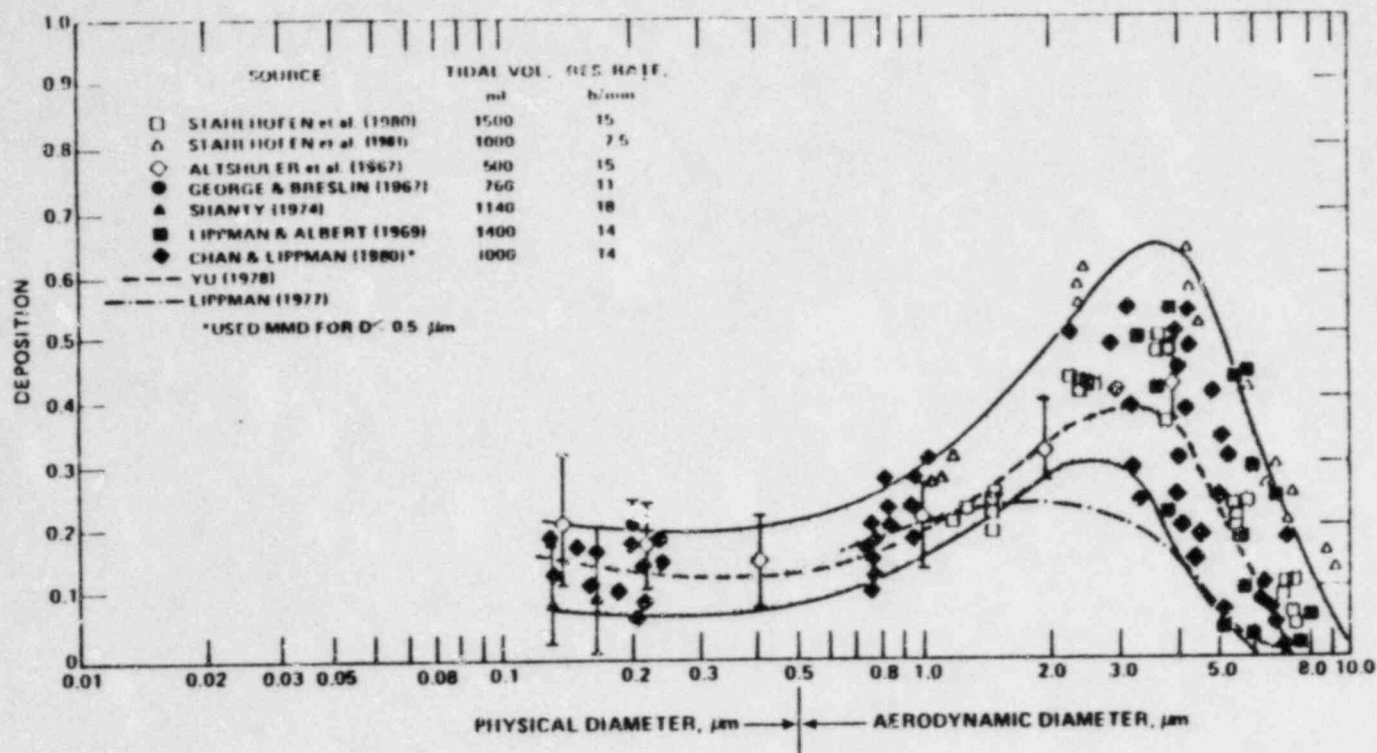
Figure 1 - Deposition of monodisperse aerosols in the pulmonary region for mouth breathing in humans as a function of aerodynamic diameter, except below 0.5 µm, where deposition is plotted vs. physical diameter. The eye-fit band envelops deposition data cited by the different investigators. The dashed line is the theoretical deposition model of Yu (1978) and the broken line is an estimate of pulmonary deposition for nose breathing derived by Lippmann (1977) - (from EPA 1982).

Radioelement	Solubility
H-3, C-14, Na-22, Na-24, I-129, I-131, I-132, I-133, I-135, Cs-134, Cs-137	Soluble
Mn-54, Fe-55, Fe-59, Co-58, Co-60, Ni-63, Sr-89, Sr-90, Zr-95, Nb-95, Ru-103, Ru-106, Te-132 Cr-51, Cu-64, Zn-65, Mo-99, Ba-140, La-140, Ce-141, Ce-144	Insoluble

This classification is based upon the recommendations of the ICRP Task Group on lung dynamics (ICRP, 1966). Thus, the model accounts for the retention characteristics of radionuclides.

There is one group of radionuclides that has not yet been addressed in this discussion about inhalation dosimetry. These are the noble gases, xenon, krypton and argon. Because of their inert nature they do not bind significantly to particles or adsorb onto surfaces. This fact is confirmed by the calculation described in Attachment 2 to this testimony. However, even if one assumes significant particle binding by noble gases, this is inconsequential to the resulting dose because the source terms of these radioactive gases would also significantly decrease due to holdup and removal of gases in the HVAC charcoal filtration system.

C. Particulate Material in the Ambient Environment

In addition to the model's consideration of particle deposition and retention behavior in the lungs, data about ambient particle size, especially coal fly ash, confirms that the model

effectively accounts for coal fly ash lung deposition and retention.

Data collected during the 1970s, which describe the distribution of atmospheric particulate matter in the United States, indicate the existence of three separate particle size modes having independent behavior in ambient air (EPA, 1982). The first mode, the nuclei mode, is below 0.1 μm and generally consists of primary particles emitted as a result of fuel combustion (oil, gasoline, natural gas and coal). These particles are formed by condensation from the gaseous phase and only exist for short times due to rapid coagulation and aggregation. The second size mode falls between 0.1μm and about 2.0μm. These particles typically remain airborne for several days, and this mode is called the accumulation mode. These particles are largely formed by coagulation of particles from the smaller mode and by aggregation of additional particles. Because of their relatively long life, these particles are the ones most easily transported from point source emissions. The third and final mode includes particles above about 2.0μm, generally produced through mechanical action and easily removed by washout and sedimentation. These particles exist in the atmosphere for only a few hours.

The most prevalent particle mode present in the atmosphere around the Shearon Harris site from an industrial source would be the accumulation mode. This is because the plant is located

in a forested region with no major industrial combustion source within five miles of the plant (FSAR Section 2.2.1). In this rural, non-industrial area, larger particles ($> 2.0\mu m$) emitted from faraway sources would not be present because they would have rapidly settled out; however, smaller particles ($< 0.1\mu m$) transported from faraway industrial sources would have aggregated and thus grown in size by the time they reach the site.

Not only can the particle size from industrial combustion sources transported to the Harris Plant vicinity generally be deduced based on area conditions, but it is possible to make certain assumptions about coal fly ash particle size in particular. The results of a survey for coal plants equipped with electrostatic precipitators show a typical size distribution for fly ash with a median aerodynamic diameter of approximately $2.0\mu m$ (Figure 2). Thus, fly ash in the atmosphere will be in the size range that is implied in the model. This is because the inhalation dose model used by Applicants and the NRC Staff assumes particle deposition fractions for the lung representative of particles in the size range of about 0.1 to $2.0\mu m$.

In summary, considering the sizes of ambient atmospheric particles generally, and fly ash in particular, it can be concluded that the inhalation dosimetry model accurately accounts for lung deposition of inhaled ambient particles including fly ash at the site.
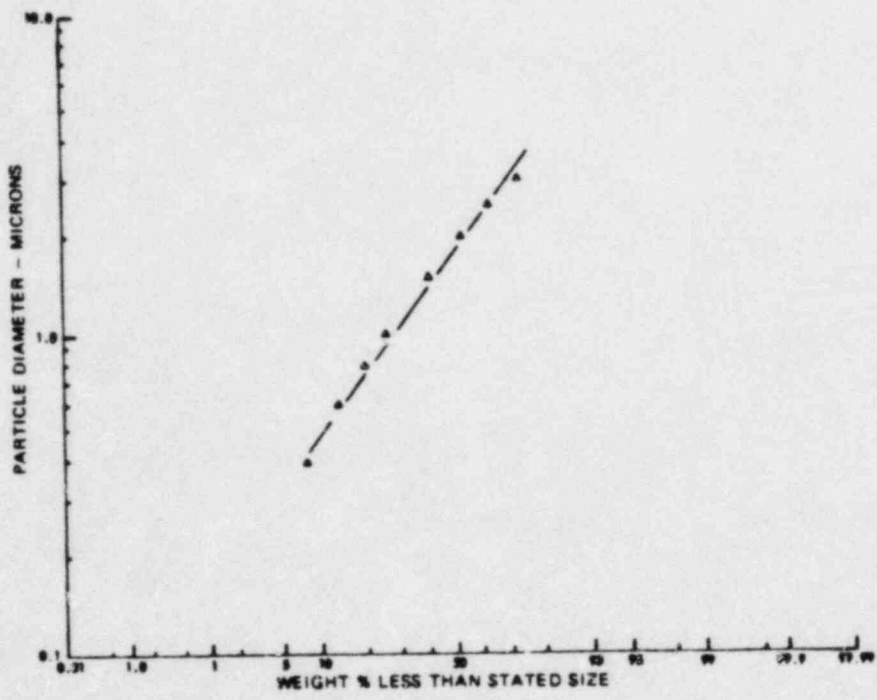
Figure 2 - Emissions from Electric Utility Power Plants
Controlled by Electrostatic Precipitators (From Natusch,
1978)

D.   Inhalation Dose Comparison

Notwithstanding the above analyses, the doses calculated for the Harris Plant vicinity would not change even if one assumes greater lung particle deposition, or longer lung retention of radionuclides (due to decreased solubility) than are assumed in the calculation performed in accordance with Reg. Guide 1.109.

Table 1 lists the breakdown of doses by organ and radionuclide. These are maximum adult doses which are expected to occur from the annual releases at Shearon Harris and were calculated using standard Reg. Guide 1.109 methodology. Based on these doses, the whole body dose is about 0.075 mrem and the critical organ dose (thyroid) is about 0.14 mrem.

Table 2 lists a similar dose breakdown; however, the doses listed in this table were calculated assuming 60 percent radionuclide deposition in the deep lung. This is the maximum fraction observed from human studies (EPA 1982) as opposed to the 25 percent deposition assumed in the model. Doses were adjusted using ICRP-30 (ICRP, 1979) correction equations for different deposition fractions. Assuming a 60 percent deposition fraction, the whole-body dose remains about 0.075 mrem, and the dose to the critical organ (thyroid) is about 0.16 mrem.

In order to assess the significance of alternative assumptions regarding solubility, another calculation was performed.

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TABLE 2

Inhalation Dose Assuming All Radionuclides 0.1um AMAD

Critical Organ (m rem)

Nuclide	Total Body	GI Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
H-3	7.44(-2)	7.44(-2)	0	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)
I-131	1.23(-4)	3.78(-5)	1.51(-4)	2.15(-4)	3.69(-4)	7.17(-2)	0	0
I-133	3.14(-5)	6.15(-5)	5.99(-5)	1.03(-4)	1.79(-4)	1.49(-2)	0	0
Mn-54	6.23(-6)	7.65(-5)	0	3.92(-5)	9.75(-6)	0	1.39(-3)	0
Fe-59	3.39(-6)	6.01(-5)	3.77(-6)	8.89(-6)	0	0	3.25(-4)	0
Co-58	6.82(-6)	3.50(-4)	0	5.21(-6)	0	0	3.05(-3)	0
Co-60	2.31(-5)	4.44(-4)	0	1.80(-5)	0	0	9.31(-3)	0
Sr-89	6.46(-7)	2.59(-5)	2.25(-5)	0	0	0	1.03(-4)	0
Sr-90	5.59(-5)	6.61(-6)	8.64(-4)	0	0	0	8.81(-5)	0
Cs-134	4.39(-4)	6.28(-6)	2.25(-4)	5.13(-4)	1.78(-4)	0	5.89(-5)	0
Cs-137	4.32(-4)	8.50(-6)	4.84(-4)	6.28(-4)	2.25(-4)	0	7.60(-5)	0
TOTAL	7.55(-2)	7.55(-2)	1.81(-3)	7.59(-2)	7.54(-2)	1.61(-1)	8.88(-2)	7.44(-2)

Table 3, which presents the results of that calculation, illustrates the dose breakdown assuming all radionuclides (except tritium) are insoluble. This calculation results in a whole body dose of about 0.74 mrem, and the critical organ dose (lung) is about 0.084 mrem.

When comparing the results listed in Tables 1 through 3, it can be seen that some organ doses increase, others decrease and others remain unchanged. However, the overall conclusion is that particle size and solubility have no significant effect on the final dose outcome.

In summary, the phenomenon of radionuclides attaching to fly ash impacts only a small fraction of the inhaled dose and, with respect to that fraction, the inhalation dose model used by Applicants and the NRC Staff effectively accounts for the attachment of radionuclides to fly ash particles in the atmosphere around the Harris Plant.

III. Doses From Particle Deposition onto Food Crops

In order to assess whether the phenomenon of radionuclides attaching to fly ash impacts the calculation made by Applicants and the NRC Staff of the food pathway dose for the Harris Plant, it is necessary to examine the assumptions used in Regulatory Guide 1.111 as to particle deposition velocities. This is because, in general, the greater the deposition rate, the higher the dose from the food ingestion pathways. Analysis of

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TABLE 3

Inhalation Dose Assuming All Radionuclides Insoluble

Critical Organ (m rem)

Nuclide	Total Body	GI Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
H-3	7.44(-2)	7.44(-2)	0	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)	7.44(-2)
I-131	7.15(-6)	1.59(-3)	1.84(-5)	4. 0(-5)	1.12(-5)	0	1.59(-3)	0
I-133	1.36(-6)	1.73(-3)	3.50(-6)	8.54(-6)	2.12(-6)	0	3.02(-4)	0
Mn-54	2.64(-6)	3.24(-5)	0	1.66(-5)	4.13(-6)	0	5.87(-4)	0
Fe-59	1.45(-6)	2.57(-5)	1.61(-6)	3.80(-6)	0	0	1.39(-4)	0
Co-58	2.84(-6)	1.46(-4)	0	2.17(-6)	0	0	1.27(-3)	0
Co-60	9.63(-6)	1.85(-4)	0	7.49(-6)	0	0	3.88(-3)	0
Sr-89	2.69(-7)	1.08(-5)	9.37(-6)	0	0	0	4.31(-5)	0
Sr-90	3.39(-5)	4.01(-6)	5.52(-4)	0	0	0	5.34(-5)	0
Cs-134	3.43(-6)	4.36(-5)	8.84(-6)	2.16(-5)	5.37(-6)	0	7.63(-4)	0
Cs-137	5.41(-6)	7.50(-5)	1.39(-5)	3.39(-5)	8.44(-6)	0	1.20(-3)	0
TOTAL	7.44(-2)	7.81(-2)	6.11(-5)	7.44(-2)	7.44(-2)	7.44(-2)	8.42(-2)	7.44(-2)

deposition velocities establishes that the food pathway dose calculation conservatively accounts for the attachment of radionuclides to fly ash particles and the effect this phenomenon may have on the rate at which radionuclides deposit on the ground.

The particle deposition velocities on which the Regulatory Guide 1.111 calculation is based were taken from Markee (1967). These velocities range from 0.12 cm/sec to 1.81 cm/sec. At issue here is the validity of these rates, assuming radionuclides are attached to fly ash particles.

EPA has published data (EPA 1982) on deposition velocities which are based on field and laboratory measurements. For particles 0.1, 1.0 and 10μm in diameter, the corresponding deposition velocity is 0.015, 0.21 and 4.0 centimeters per second. The median size of fly ash is about 2μm. See Figure 2. Therefore, an appropriate deposition velocity for fly ash is slightly above 0.21μm/sec. This is well within the range assumed in Regulatory Guide 1.111. Thus, the assumed deposition velocities are appropriate, if not conservative for fly ash particles.

IV. Conclusion

In summary, the inhalation dose conversion factors used by Applicants and the NRC Staff appropriately account for radionuclide adsorption onto respirable fly ash in the ambient

atmosphere. In addition, the calculation of doses from the crop-food-chain pathway appropriately accounts for the binding of radionuclides to particles deposited onto the ground, pasture and crops.

Resume

JOHN J MAURO

Education:	BS - Long Island University 1963 MS - New York University 1970 PhD - New York University Medical Center - Institute of Environmental Medicine 1973
Awards:	- Alvin Gruder Memorial Award for Excellence in Biological Sciences - Member of the Optimates Society for Academic Achievement - Founder's Day Award for Doctoral Dissertation
Societies:	- Health Physics Society - American National Standards Committee on Emergency Planning
Certifications:	Certified by the American Board of Health Physics
Consultancies:	- Radiological Health Bureau of the California Office of Emergency Services - Battelle Memorial Institute - Louisiana Power and Light Company - Shaw Pittman, Potts and Trowbridge - EG&G Idaho - Union Carbide Corporation - Nuclear Division
Current Position:	Director of the Radiological Assessment and Health Physics Department of Envirosphere Company in New York City.

Summary of Professional Experience:

While a graduate student at the Institute of Environmental Medicine of New York University, I was also a full-time Research Assistant from 1970 to 1973. In this position I assisted Principal Investigators on numerous research projects on the ecology and radioecology of the lower Hudson River Estuary. These activities included the collection of aquatic organisms from the estuary to determine species abundance and diversity, the life history of white perch and the concentration of radionuclides in aquatic organisms, water and sediment. These activities also included experimentation into the ability of microorganisms collected from the Hudson River sediment to organify inorganic mercury.

In addition to my responsibilities as Research Assistant, I was a full-time graduate student, studying environmental health, health physics and radioecology. My doctoral research was on the radioecological behavior of Cs-137 in the lower Hudson River Estuary. Research for my thesis covered a three-year period which included extensive field studies and laboratory experimentation to identify and mathematically model the uptake and elimination of Cs-137 by aquatic organisms.

After receiving my doctoral degree in 1973, I joined Ebasco Services as a Radiological Assessment Engineer. Ebasco Services is a major architect-engineer-constructor for power generating facilities. My initial responsibilities at Ebasco were to evaluate the radionuclide release rates from proposed and operating nuclear power facilities under normal plant operation and following postulated accidents, and to determine the radiation exposures and health risks to workers and members of the nearby general population. In this capacity I developed several models for performing radiological impact assessment, and have prepared the radiological impact assessment sections of license applications.

Since joining Ebasco I have held positions of increasing responsibility, and am currently Director of the Radiological Assessment and Health Physics Department in Envirosphere Company, the Nuclear Licensing and Environmental Health Division of Ebasco Services. In this position, I report directly to the Vice President of Nuclear Operations and, I am responsible for all radiological health and emergency planning services provided by Envirosphere Company. I manage a technical staff of 10 senior level consultants with advanced degrees in nuclear and biological sciences, with a combined 150 years of professional experience in technological risk management.

My responsibilities as Director of the department are divided into radiological health consulting (40%), project management (30%), marketing and business development (20%), and department administration (10%). A brief description of each of these areas of responsibilities follows.

Though my management responsibilities have increased considerably since joining Ebasco, I continue to personally provide consulting services to our clients. These services include the analysis of radiological source terms, environmental transport, radio-ecology, internal and external dosimetry, health risk assessment, radiological surveillance, emergency planning, regulatory analysis and the preparation and defense of expert testimony on these subjects. Recently I have also become involved in the evaluation of toxic chemical hazards at industrial sites and low-level radioactive waste management. These services have been provided for a large number of clients representing the nuclear power industry and federal and state agencies and their subcontractors.

I have also managed several consulting contracts in the areas of radiological and chemical toxicology, health physics, and emergency planning. A detailed description of these projects will be provided upon request. Most of these projects have been of a multidisciplined nature and included participation of specialists in the areas of toxicology, nuclear engineering, mathematical modelling, meteorology, hydrology and computer sciences. On these projects I had overall responsibility for budget, schedule and technical quality of deliverables.

As director of the Radiological Assessment and Health Physics Department, I am also responsible for developing and meeting an annual budget. The budget includes staff and non-staff salaries and out-of-pocket expenses for client billable work, department overhead and business development. My effectiveness as Director is judged by my ability to achieve or exceed the budget for billable work and to effectively control non-billable expenses. Non-billable expenses include business development, training and publications, presentations, participation on standards committees and other professional practices. I have responsibility for hiring new staff and for staff performance review, promotions and merit increases. In this capacity I am assisted by 2 department managers who report directly to me.

Publications and Presentations:

Mauro, J J and M E Wrenn 1972. A Review of Radiocesium in Aquatic Biota. Presented at the Health Physics Society Annual Meeting, Las Vegas, Nevada, June 12-16, 1972.

Mauro, J J and M E Wrenn 1973. Reasons for the Absence of a Trophic Level Effect for Radiocesium in the Hudson River Estuary. Presented at the IRPA meeting held in Washington, D C in October. Published in the proceedings of that meeting.

Mauro, J J and J Porrovecchio 1976. Numerical Criteria for In-plant As Low as is Reasonably Achievable. In "Operational Health Physics". Proceedings of the 9th Mid-Year Topical Symposium of the Health Physics Society.

Mauro, J J, D Michlewicz and A Letizia 1977. Evaluation of Environmental Dosimetry Models for Applicability to Possible Radioactive Waste Repository Discharges, Y/OWI/SUB-77/45705.

Mauro, J J 1978. Comparison of Gaseous Effluent Standards for Nuclear and Fossile Fuel Power Production Facilities. Proceedings of the December 1979 Annual Meeting of the American Nuclear Society.

J Thomas, J J Mauro, J Ryniker and R Fellman 1979. Airborne Uranium, Its Concentration and Toxicity in Uranium Enrichment Facilities, K/PO/SUB -79/31057/1, February.

Lind K E, Mauro, J J, J D Levine, L Yemin, H J Howe, Jr and C W Pierce 1979. Safety Related Research Required to Support Future Fusion Research Reactors. Presented at the Annual Meeting of the American Nuclear Society-San Francisco, November, 1979.

O'Donnell E P, and Mauro J J 1979. A Cost-Benefit Comparison of Nuclear and Nonnuclear Health and Safety Protective Measures and Regulations. Nuclear Safety, Vol 20 No. 5, September-October, 1979.

Mauro, J J 1980. A Real Time Computer Program for Offsite Radiological Impact Assessment. Presented at the 1980 Annual Meeting of the American Nuclear Society. TANSAO 34 1-899.

Bhatia R, Mauro, J J and G Martin 1980. Effects of Containment Purge on the Consequences of a Loss of Coolant Accident. Presented at the 1980 Annual Meeting of the American Nuclear Society. TANSAO 34 1-899.

Marschke S, and Mauro, J J 1980. Radiocesium Transport Into Reservoir Bottom Sediments - A Licensing Approach. Presented at the 1980 Annual Meeting of the ANS. TANSAO 34 1-899.

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Mauro, J J and E P O'Donnell 1982. The Role of the Architect/ Engineer in the Emergency Planning Process. Presented at the Annual Meeting of the American Nuclear Society. June 6-10, 1982.

Mauro, J J and W R Rish 1982. Dealing with Uncertainties in Examining Safety Goals for Nuclear Power Plants. In NUREG-CP-0027. Proceedings of the International Meeting on Thermal Reactor Safety.

Mauro, J J, S Schaffer, J Ryniker, and J Roetzer. Survey of Chemical and Radiological Indices Evaluating Toxicity. National Low-Level Radioactive Waste Management Program. DOE/LLW-17T. March, 1983.

Vold E, J J Mauro and D Michlewicz 1984. Dose Projection for Nuclear Emergency Response on a Microcomputer. Published in "Computer Applications in Health Physics." Proceedings of the Health Physics Midyear Topical Meeting, Pasco, Washington. February 5-9, 1984.

Mauro, J J, S Schaffer, W Rish and J Parry. Application of Probabilistic Techniques to Dose and Risk Assessment Performed by EPA in Support of 40 CFR 191. Submitted for Publication.

STEVEN A. SCHAFFER
Senior Radiological Assessment Engineer

SUMMARY OF EXPERIENCE (Since 1973)

Total Experience - Ten years experience in the design and
implementation of research and assessment projects addressing
the problems of environmental contamination and human health
affairs.

Education -   PhD, Biology/Environmental Health Science,
                 New York University, June 1982

                 MS, Biology, 1978, New York University

                 BS, Biology, 1973, State University of New York,
                 Oneonta

REPRESENTATIVE ENVIROSPHERE PROJECT EXPERIENCE (Since 1981)

High Level Waste

Provide technical and regulatory support to the DOE concerning
the proposed EPA standard on high-level waste (40 CFR 191).
This support included:

1.   Co-authoring a report submitted by the DOE to the EPA Sci-
      ence Advisory Board. This work quantified the uncertainty
      in the EPA health risk estimates used as the basis of the
      proposed regulation.

2.   Critically evaluated the REPRISK methodology used by the
      EPA for determining the risk from high-level waste.

3.   Acted as a technical liaison between DOE and EPA espe-
      cially in the area of environmental transport.

Provided technical and regulatory support to the DOE concerning
high-level waste disposal in salt. Responsibilities included
formulating a safety plan for a salt repository and developing
technical interpretations of current high level waste regula-
tions.

Low-Level Waste

Aided in the preparation of a toxicity index for the radio-
logical and toxicological hazard in low-level waste for the
DOE.

General Radiological Assessment

Evaluated the radiological impact of nuclear power plant oper-
ation for Ebasco client utilities. Prepared postulated source
terms and subsequent doses to surrounding areas for Safety
Analysis and Environmental Reports.

Aided in the preparation of testimony on the synergistic action
of radiation and chemical carcinogens.

Assisted in the preparation and implementation of an environ-
mental radiological monitoring program for a nuclear power
plant.

Prepared testimony on the radiological effects of coal fired
electric generating facilities.

Developed uncertainty distributions for environmental pathway
model parameters that were utilized in an uncertainty analysis
of the environmental risks of high-level waste.

PRIOR EXPERIENCE (8 Years)

Research Scientist

New York University Medical Center, Institute of Environmental
Medicine, Laboratory for Environmental Studies, Tuxedo, New
York 10987.

Member of a research group for 3 years, examining the transport
and ultimate fate of nuclear reactor produced radionuclides
discharged into the Hudson River estuary. Responsible for the
Beta/Gamma emitting nuclide portion of this project.

Conducting Ph.D thesis research on the effects of alpha radia-
tion and polychlorinated biphenyls (PCBs) on the biochemical
energy production of algae.

Assisted in laboratory and field research which analyzed the
aerobic and anaerobic degradation of PCBs.

Assisted in a field and laboratory research program which stud-
ied the biological and physical transport of PCBs and heavy
metals in the Hudson River.

Carried out and subsequently published the results of labora-
tory experiments dealing with the effects of high LET radiation
on the survival and energy metabolism of algae.

Supervised and conducted, for 5 years, field sampling programs
for nuclear power plant entrainment studies on the Hudson
River. Solely responsible for a research project designed to
assess the effects of different sampling gear on
icthyoplankton.

Assisted in an ichthyoplankton population survey of the Hudson River.

Conducted and reported on thermal tolerance and chlorination bioassays with fish and numerous invertebrate plankton as part of a nuclear power plant entrainment study.

Masters research involving the quantitative and qualitative chemical analysis of Hudson River water.

Publications

O'Connor, J.M. and S.A. Schaffer, 1977. The Effects of Sampling Gear on the Survival of Striped Bass Icthyoplankton, Chesapeake Science 18:312-315.

Schaffer, S.A. and C.C. Lee. Organic Carbon and Protein Concentrations of Hudson River Water in the Vicinity of Indian Point. (abstract) American Society of Limnology and Oceanography Annual Meeting, 1978.

Steinhausler, F., S.A. Schaeffer, N. Cohen, C.C. Lee, J.M. O'Connor, M.E. Wrenn. Effects of High LET Radiation on Intracellular ATP Content of Prokaryotic and Eukaryotic Algae. Abstracts of the 26th Annual Meetings of Radiation Research Society, Toronto, Canada, May 1978. Radiation Research 74:591-92.

Steinhausler, F., S.A. Schaffer, C.C. Lee, J. O'Connor, and M.E. Wrenn, 1980, Effects of Low-Level Alpha Radiation on Intracelular Energy Metabolism. Radiation Research 81:393-401.

Rish, W.R., J.J. Mauro, S.A. Schaffer. 1983. Uncertainties in EPA Modeling Used to Develop Draft Standard 40 CFR 191. Proceedings of the American Nuclear Society, Winter 1983.

Schaffer, S.A. (accepted for publication). The bioenergetic response of chlorella vulgaris to alpha radiation. Environmental and Experimental Botany.

Professional Societies

Society of Environmental Toxicology and Chemistry (SETAC).

Attachment 2

Adsorption of Noble Gases onto Airborne Fly Ash

The fraction of the annual release of radioactive noble gas from the Shearon Harris site absorbed onto airborne fly ash particles can be estimated by the following relationship:

$$\text{Fraction Absorbed} = \frac{\text{Conc.}_{fa}}{\text{Conc.}_t}$$

Where $\text{Conc.}_{fa} = \dfrac{\text{weight of fly ash (g)}}{m^3} \cdot K_d \dfrac{g}{g}$

$$\text{Conc.}_t = \frac{\text{stable gas (g)}}{m^3} + \frac{\text{radioactive gas (g)}}{m^3}$$

Using these equations, we have calculated the fraction absorbed onto fly ash for Kr-85, Xe-133 and Ar-41. These radionuclides were chosen because they represent the three elemental types released and are the worst case combination of half-life and release quantity.

Table A-1 lists the various parameters used in our calculation and Table A-2 lists our results. In summary, an insignificant fraction of radioactive noble gases released from Shearon Harris would become associated with airborne fly ash particles. It should be noted that the actual fraction would probably be lower than the quantity calculated, because the calculation assumes a fly ash concentration representative of the maximum total respirable airborne particle load for

northeastern cities, which is a higher concentration than exists in the vicinity of the Harris Plant (Pedco 1982, EPA 1982). Moreover, our calculation is additionally conservative because it assumes that all particles have surface adsorption characteristics of activated charcoal, which is manufactured for the specific purpose of efficiently adsorbing radionuclides.

Table A-1

List of Parameters

Parameter	Value	Notes
Fly ash concentration (g/m^3)	1×10^{-4}	1
Adsorption coefficient (g/g)		
Krypton	1.5×10^{-10}	
Xenon	2.3×10^{-9}	2
Argon	1.07×10^{-11}	
Concentration of stable gas in atmosphere (g/m^3)		
Krypton	3.8×10^{-3}	
Xenon	2.9×10^{-4}	3
Argon	1.6	
Radioactive gas concentration in atmosphere (g/m^3)		4
Krypton-85	1.7×10^{-6}	
Xenon-133	4.4×10^{-6}	
Argon-41	1.9×10^{-12}	

Notes:

1.   The concentration of all respirable particles in large industrial N.E. cities can be as high as 1×10^{-4} g/m^3 (Pedco 1982). The calculation assumes the fly ash concentration around Shearon Harris site to be equal to this concentration.

2.   Adsorption coefficients for fly ash was assumed to be the same as activated charcoal (NUREG-0678) divided by a reduction factor of 332 to account for the difference in specific surface area.

3.   Taken from CRC Handbook of Chemistry and Physics 64th ed.

4.   Concentration of radioactive noble gases was calculated by multiplying the annual site releases by the annual average atmospheric dispersion factor for the critical residence $(3.2 \times 10^{-6} \ sec/m^3)$.

Table A-2

Fraction of Annual Release of Radioactive Noble Gases
Absorbed to Airborne Fly Ash Particles

Radionuclide	Fraction Absorbed
Kr-85	1.2×10^{-5}
Xe-133	2.4×10^{-3}
Ar-41	2.0×10^{-9}

References

CRC Handbook of Chemistry and Physics 64th ed. 1983-1984 R.C. Weast [ed.], CRC Press, Inc., Boca Raton, Fla.

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ICRP. 1979-82. Limits for intakes of radionuclides by workers. ICRP Publication 30. Pergamon Press, Oxford.

Markee, E.H. Jr. 1967. A parametric study of gaseous plume depletion by ground surface adsorption, in Proceedings of USAEC Meteorological Information Meeting, C.A. Mawson [ed.], AECL-2784: 602-613.

Natusch, D.F.S. 1978. Potentially carcinogenic species emitted to the atmosphere by fossil-fueled power plants. Environmental Health Perspective Vol. 22: 79-90.

NUREG-0678. The effects of temperature, moisture, concentration, pressure and mass transfer on the adsorption of krypton and xenon on activated carbon.

Pedco, 1982. Compilation of ambient particulate matter size and composition data. Pedco Environmental Inc.

Regulatory Guide 1.109. 1977. Calculation of annual doses to man from routine releases of reactor effluents for the purpose of evaluating compliance with 10 CFR part 50, Appendix I. Rev. 1., U.S. Nuclear Regulatory Commission.

Regulatory Guide 1.111. 1977. Methods for estimating atmospheric transport and dispersion of gaseous effluents in routine releases from light-water-cooled reactors. Rev. 1., U.S. Nuclear Regulatory Commission.