Chapter 9

RADIOLOGICAL DOSE ASSESSMENT

This chapter presents the potential radiological doses to off-site individuals and the surrounding population from BNL airborne effluents, liquid effluents, and special case exposure scenarios, such as the consumption of fish or deer meat. These potential doses are based on calculations using 1997 effluent data and conservative intake and exposure assumptions. All doses are expressed as committed effective dose equivalents (50-year committed dose), or EDE, from internal deposition of radionuclides. Use of the effective dose equivalent allows doses from different types of radiation to different parts of the body to be expressed on the same relative risk scale. Appendix B describes the calculational methods used.

9.1 Effective Dose Equivalent Calculations - Airborne Pathway

Brookhaven National Laboratory is subject to the requirements of Title 40 CFR Part 61, Subpart H, National Emission Standards for Hazardous Air Pollutants (NESHAPs). This EPA Rule establishes national policy on the airborne emission of radionuclides. It specifies the monitoring and reporting requirements for various types of radionuclides and establishes the public dose limit for the airborne pathway as 10 mrem (0.1 mSv) per year.

9.1.1 Air Dispersion Model

The NESHAPs regulations require the use of the CAP88-PC (Clean Air Act Assessment Package-1988) computer model in demonstrating site compliance. The model uses a Gaussian plume equation to estimate the average dispersion of radionuclides released from elevated stacks or area sources (EPA, 1992). The program computes radionuclide concentrations in air, rates of deposition on ground surfaces and concentrations in food (where applicable) to arrive at a final value for projected dose at the specified distance from the release point to the location of interest. The program supplies both the calculated EDE to the maximally exposed individual, and the collective population dose within an 80-km radius of the emission source(s). This model gives very conservative dose estimates in most cases.

Input parameters used in the model include radionuclide type, emission rate in curies per year, and stack parameters, such as height, diameter and exhaust velocity of the effluent. Site-specific weather data supplied by measurements from BNL's meteorological tower are used, including wind speed, direction, frequency and temperature. A 10-year average data set for these meteorological parameters is used. Population data for the surrounding area is based on customer records of the Long Island Lighting Company.

For modeling the dose to the maximally exposed individual (MEI), all emission points are co-located at the center of the developed portion of the site (approximately, at the location of the HFBR stack). Due to the wind frequency distribution on-site, the maximum dose is consistently projected in the NNE sector. The distance from the HFBR stack to the nearest residences adjacent to the site boundary in the NNE direction is approximately 3,000 meters. Placement of the MEI at 3,000 meters NNE was initiated with the 1995 Site Environmental Report. Earlier, the MEI was assumed to be at the geographically closest boundary (to the west), only 1500 meters away. However, due to the consistent wind patterns in the area, it is more accurate to locate the MEI in the NNE sector, this somewhat reduces the total dose from the airborne pathway compared to years before 1995.

9.1.2 Fugitive Sources

In addition to point sources such as stacks, 'area' or 'diffuse' sources, which do not have dedicated exhaust systems (also known as 'fugitive' sources), must also be evaluated for airborne emissions.

The only potential fugitive emission sources in CY 1997 were the RA V Recharge Basin and the STP holding ponds.

The RA V Recharge Basin, which receives water pumped from the southern edge of the HFBR tritium plume, was evaluated in 1997 before the start of operations using conservative estimates of what maximum tritium concentrations might be. The tritium concentrations of the groundwater reaching the recharge basin were expected to be about 3,500 pCi/L (130 Bq/L) or less. However, for the assessment, more conservative assumptions were made; it was assumed that the water contains 20,000 pCi/L (740 Bq/L) of tritium, the drinking water standard. The dose to the MEI residing at the site boundary, northeast of the center of the Laboratory was calculated to be 2.5E-6 mrem/yr. In actuality, analysis of the water processed at the Basin showed that tritium was rarely detectable in the pumped water. Out of 37 water samples collected at the Basin in CY1997, from May (the beginning of operations) through December, only two showed tritium above the detection limit, with a maximum concentration of just 1,820 pCi/L (67 Bq/L). Therefore, the RA V Basin was not realistically a diffuse emissions source due to a lack of significant source activity. Monitoring for airborne tritium in the vicinity of the Basin confirms this (Chapter 7).

Since the STP holding ponds no longer receive distillate from the Waste Concentration Facility, they contained only trace quantities of tritiated water compared to earlier years. However, since these ponds provide the opportunity for airborne radionuclide generation through evaporation, they were evaluated as fugitive sources. The conservative assumption was made that the maximum source inventory measured in the ponds in 1997 represented the inventory throughout the year. The tritium inventory of Pond No. 1 was the greater of the two at approximately 0.03 Ci (1.1 GBq). Assuming a 10% loss of this inventory due to evaporation, the dose to the MEI is 8E-8 mrem.

9.1.3 Total Dose from the Airborne Pathway

In 1997, the effective dose equivalent to the MEI adjacent to the NNE boundary of the site from all radiological airborne emissions sources combined was 0.07 mrem (0.7 µSv). This is equal to the calculated value for 1996. Argon-41 released from the BMRR contributed 98% of this dose. By comparison, this is 143 times less than the EPA airborne dose limit of 10 mrem (0.1 mSv) and 4,286 times smaller than the EDE received annually from natural background radiation. This dose is too small to distinguish from background radiation sources using the most sensitive environmental TLDs. Table 9-1 shows the MEI dose projected for effluents from each facility.

9.2 Effective Dose Equivalent Calculations - Water Pathway

Since the Peconic River is not used as a drinking water supply, nor for irrigation, its waters do not constitute a direct pathway for the ingestion of radioactive material (NYSDOH, 1993). However, water in the Peconic River does recharge to the underground aquifer, which is used as a drinking water supply for residential homes. Analyses of water samples from several private wells in Manorville, east of the Laboratory, have shown the presence of tritium since analyses began in 1986. For evaluating the potential maximum EDE to an individual from water ingestion, the results from the radiological analysis of these private wells were used. In 1997, all samples were collected and analyzed by the SCDHS.

Tritium was the only BNL-related radionuclide detected in any of these private wells. The maximum tritium concentration in a residential well in 1997 was 2,201 pCi/L (81 Bq/L), nine times less than the 20,000 pCi/L (740 Bq/L) limit established by the EPA National Primary Drinking Water Regulations under the Safe Drinking Water Act. In calculating the potential dose to an individual via the drinking water pathway, it is conservatively assumed that this maximum concentration is consumed at a rate of 2 liters per day for 365 days a year. Under these assumptions, the dose to the maximally exposed individual via this pathway is 0.1 mrem (1 µSv), or 2.5% of the 4 mrem (40 µSv) dose limit specified for this pathway by the SDWA.

Table 9-1
BNL Site Environmental Report for Calendar Year 1997
Radiological Dose due to Airborne Effluents as Calculated by CAP88-PC

Building	Facility or Process	Construction Permit No.	MEI Dose (mrem)*	Collective Dose (person-mrem)	Notes
491	BMRR	None	6.9E-02	3.5E+03	
705	HFBR	None	8.0E-05	9.8E+00	
931	BLIP	None	7.3E-05	3.1E-02	
801	Target Processing Lab	None	1.8E-06	2.3E-01	
705	Evaporator Facility	BNL-288-01	1.3E-05	1.8E+00	
1005	RHIC Accelerator	BNL-389-01	N.D.	N.D.	
—-	AGS Booster	BNL-188-01	0	0	(a)
490	Radiation Therapy Facility	BNL-489-01	2.2E-04	9.3E-03	(b)
820	Accelerator Test Facility	BNL-589-01	N.D.	N.D.	(c)
938	REF/NBTF	BNL-789-01	N.D.	N.D.	(d)
510	Calorimeter Enclosure	BNL-689-01	N.D.	N.D.	(e)
—-	STP Holding Ponds	None	8.4E-08	8.3E-05	
463	Biology Dept.	None	2.3E-07	1.3E-02	(f)
555	Chemistry Dept.	None	1.5E-09	1.1E-04	(f)
318	Dept. of Applied Science	None	4.0E-05	2.8E+00	(f)
490A	Dept. of Applied Science	None	2.3E-07	1.2E-02	(f)
490	Medical Research Center	None	3.1E-07	2.2E-02	(f)
703W	Dept. of Advanced Tech.	None	3.3E-09	1.6E-04	(f)
New Processes Evaluated in 1997					
—-	OU V Recharge Basin	None	2.5E-06	2.5E-03	(g)
750	HFBR Canal Dewatering	None	6.0E-05	8.8E+00	(b)
830	Kinetic Mixer	None	3.2E-05	1.4E+00	(b)
701	BGRR Deep Drain Sump	None	8.0E-08	3.9E-03	(b)
		Total	**7.0E-02**	**3.5E+03**	

*1 mrem = 0.01 mSv.
N.D. = "No Dose", facility did not operate in 1997.
MEI = Maximally Exposed Individual.
Notes: (a) Booster ventilation system prevents air release through continuous air recirculation.
(b) Based on conservative engineering calulations.
(c) This has become a zero-release facility since original permit application.
(d) The Radiation Effects Facility is no longer in use. It may be converted into a medical Proton Therapy Facility at a future date.
(e) The Calorimeter Enclosure is no longer in use.
(f) All doses based on emissions calculated using 40 CFR 61, Appendix D methodology.
(g) Based on pre-operational estimates. This value over-estimates actual dose.

9.3 Effective Dose Equivalent Calculations - Fish Consumption

Calculations were also made of the potential dose to an individual consuming fish taken exclusively from Donahue's Pond, fed by the Peconic River. Fish from this and other Peconic locations continue to be analyzed for radiological content because of known radionuclide discharges from the BNL Sewage Treatment Plant, primarily in the 1960s. In 1997, samples were analyzed for gamma-emitting radionuclides only; no analyses for strontium were performed. The maximum concentration of cesium-137 found in fish taken from Donahue's Pond was of the *chain pickerel* species: 0.46 pCi/g (17 mBq/g). This result was obtained from the whole fish, without discrimination between flesh, bone, and viscera.

For the dose evaluation, an individual is assumed to eat 7 kg (15.4 lbs.) of fish during the year. Exclusive consumption of chain pickerel at this rate and concentration would result in an EDE of 0.16 mrem (1.6 µSv) due to cesium-137. By comparison, the average individual EDE caused by the ingestion of naturally-occurring radionuclides in the United States is about 40 mrem (0.40 mSv) per year (NCRP, 1987).

9.4 Effective Dose Equivalent Calculations - Meat Consumption

As part of the environmental surveillance program, measurements were made of flesh samples collected from deer taken on BNL property (see Section 7.5.1 for details) and from off-site locations. More cesium-137 was detected in meat samples from on-site deer than in comparable deer from off-site. While on-site sport hunting is not permitted, there are no physical barriers preventing deer from migrating beyond the site boundary. Therefore, deer with elevated cesium concentrations may be taken by hunters.

The NYSDEC Wildlife Branch estimates that consumption of deer meat ranges between 2 to 9 kg (4 to 20 lbs.) per person per year. However, the NYSDOH recommended using a maximum upper bound value for consumption of 30 kg (67 lbs.) for dose calculations. Basing the calculation of the maximum individual committed EDE on this value, and assuming a cesium-137 concentration equal to the highest observed concentration of 6.0 pCi/g (0.2 Bq/g), the committed EDE would be 9.0 mrem (0.09 mSv).

9.5 Collective Dose Equivalent

While the EDE measures the radiation dose to an individual, the collective effective dose equivalent is a value used to estimate potential health risks to an exposed population. For the air exposure pathway, the CAP88-PC model provides collective EDE estimates using population data for the area within an 80-kilometer radius of the BNL site. The population data is broken into the number of people living within each of the 16 compass sectors at 16-km radial intervals. Argon-41 emitted from the BMRR was the largest contributor to the total collective dose at 3,500 person-mrem (35 person-mSv), constituting 99% of the total collective dose projected for the population within an 80-km radius of the Laboratory.

The collective EDE to the community using the private water source described in Section 8.1.4 (assumed to be not more than 500 persons) would be 50 person-mrem (0.5 person-mSv).

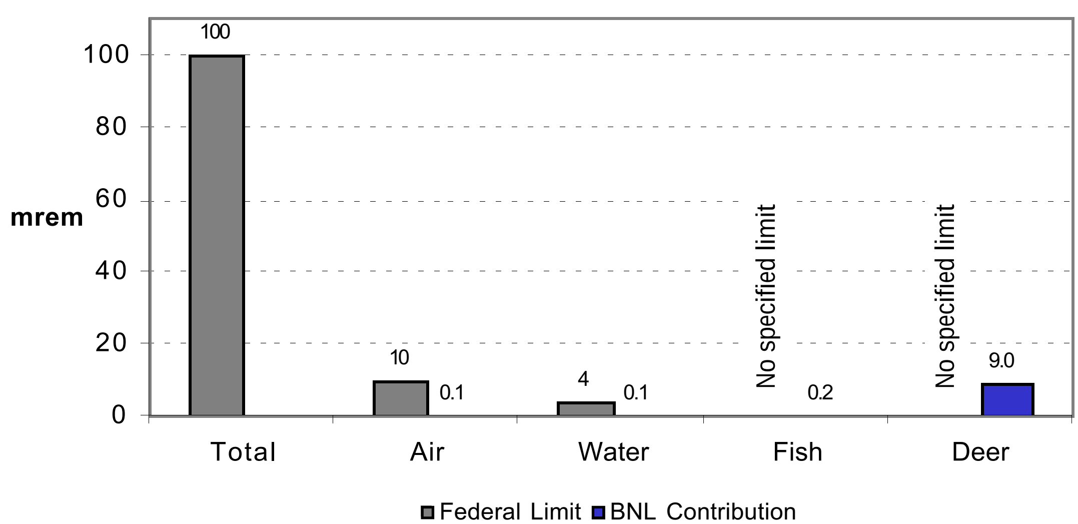

Figure 9-1. Dose summary, maximum BNL contribution and Federal limits

Table 9-2. Summary of Dose from all Environmental Pathways

Pathway	Primary Contributing Radionuclide(s)	Maximum Individual EDE (mrem)	Regulatory Pathway Limit (mrem)	Collective EDE (person-mrem)
Air	Ar-41	0.07	10	3500
Water	H-3	0.1	4	50
Fish	Cs-137	0.16	NS	100
Deer Meat	Cs-137	9.0	NS	NA

Notes:
1. 1 mrem = 0.01 mSv.
2. EDE = Effective Dose Equivalent.
3. NS = None Currently Specified
4. NA = Not Applicable
5. Because all doses in Table 9-2 are calculated rather than measured, they are potential rather than actual doses.
6. The fish dose is based on cesium-137 concentrations only. Strontium-90 analyses were not performed on fish samples collected in 1997.
7. Deer dose is based on maximum cesium-137 concentrations observed in deer collected on-site. On-site sport hunting is not permitted.
8. Deer dose assumes consumption of 30 kgs (67 lbs.) of meat in a year.

This assumes that each of these 500 people consumes water which contains the highest concentration of tritium observed in all of 1997. Finally, the number of individuals who routinely consume fish taken from Donahue's Pond was estimated to be no greater than 625 (LILCO, 1996), giving a collective EDE of 100 person-mrem (1.0 person-mSv) due to cesium-137.

By comparison, the collective dose due to external radiation from natural background to the population within an 80 km radius of the Laboratory amounts to approximately 291,000 person-rem (2,910 person-Sv), and about 196,800 person-rem (1,968 person-Sv) from internal radioactivity in the body from natural sources (excluding potential radon contributions).

9.6 Summary and Conclusion

Calculations of effective dose equivalents from all BNL facilities which have the potential to release radionuclides to the atmosphere indicate that radiological doses attributable to Laboratory operations were far below the limits established by Federal regulations. Direct measurement of external radiation levels by TLD confirms that exposure rates at the site boundary are consistent with background levels observed throughout New York State (NYSDOH, 1993).

The EDEs discussed are based on the maximally exposed individual for each scenario using the stated assumptions. It is not plausible that any single person could receive a radiological dose equal to the sum of these individual pathways. For this to occur, an individual would be required to breathe air, consume water, fish and deer at the highest radionuclides concentrations calculated or observed in all samples collected in 1997. However, even if these pathways were to be summed, the total dose from all pathways would equal 10% of the 100 mrem/yr (1 mSv/yr) DOE limit established to protect the public. This total represents approximately 3% of the average individual dose received annually from natural background sources, including radon (NCRP, 1987). These maximum credible doses demonstrate that in 1997, radioactive material associated with BNL operations had no impact on the health of the public or the environment in the surrounding area.