6.0 Radiation Dose

Results in Brief: 2009 Estimated Doses

Airborne Emissions—The estimated maximum effective dose equivalent at the site boundary from 2009 airborne emissions (excluding radon) was 0.034 mrem/yr (0.00034 mSv/yr), which is 0.34 percent of the EPA NESHAP 10-mrem/yr dose limit.

Direct Radiation—The estimated 2009 effective dose equivalent at the northeastern boundary of the site was 9 mrem/yr (0.09 mSv/yr). This is 9 percent of the 100-mrem/yr (1-mSv/yr) DOE limit.

Dose to the MEI—The dose to the MEI for 2009 was estimated to be 9 mrem/yr (0.09 mSv/yr) at the northeastern boundary of the site. This is 9 percent of the 100-mrem/yr (1-mSv/yr) DOE limit.

This chapter provides the estimated 2009 dose to the public from air and direct radiation pathways and to aquatic organisms from remedial actions associated with the groundwater restoration program. EPA NESHAP regulations require the Fernald Preserve to demonstrate that the site's radionuclide airborne emissions are low enough to ensure that no one in the public receives an effective dose of 10 mrem/yr (0.1 mSv/yr) or more. Moreover, to determine whether the Fernald Preserve is in compliance with the DOE effective dose limit of 100 mrem/yr (1 mSv/yr) from all exposure pathways (excluding radon), estimates of dose due to direct radiation are combined with airborne emissions to estimate the total dose to the maximally exposed individual (MEI). This estimate reflects the incremental dose above background that is attributable to the site.

This chapter also provides an assessment of dose to aquatic organisms that may be affected by the site's effluent to nearby streams and rivers. An assessment of dose to biota (i.e., aquatic and terrestrial organisms) is one of the requirements of DOE Order 5400.5. By limiting the dose to aquatic organisms, DOE Order 5400.5 seeks to limit the severity and likelihood of off-site environmental impacts attributable to the aquifer restoration effort at the Fernald Preserve. The dose assessment to biota is performed through the use of a computer model that estimates dose from measured radionuclide concentrations in Paddys Run and effluent discharged to the Great Miami River.

6.1 Estimated Dose from Airborne Emissions

The estimated dose from 2009 airborne emissions was calculated from annual average radionuclide concentrations measured at the six air particulate monitoring locations (one background and five site boundary locations; see Figure 5–1). The annual average background concentration was subtracted from the boundary concentrations to derive the net annual average concentration for each airborne radionuclide. Dose estimates were determined by converting the net annual average radionuclide concentrations to doses using values listed in 40 CFR 61 (NESHAP) Subpart H, Appendix E, Table 2. Appendix D contains the detailed accounting of the data.

The maximum effective dose at the site boundary from 2009 airborne emissions was estimated to be 0.034 mrem/yr (0.00034 mSv/yr) and occurred at AMS-6 along the western boundary of the site. This dose estimate is based on the conservative assumption that a person remains outdoors at the AMS-6 location 24 hours a day for the entire year; the actual dose received by this receptor would be lower than 0.034 mrem/yr (0.00034 mSv/yr), because the nearest residence is located approximately 1.5 miles (2.4 km) downwind from AMS-6. The 2009 maximum site boundary dose is slightly higher than the 2008 value (0.017 mrem/yr [0.00017 mSv/yr]).

Figure 6−1 provides a comparison between the air-pathway doses at the background and maximum boundary locations with the annual NESHAP limit of 10 mrem/yr (0.1 mSv/yr). The background and maximum boundary doses shown on Figure 6−1 are due to the airborne concentration of radium, thorium, and uranium. The maximum air-pathway dose of 0.034 mrem/yr (0.00034 mSv/yr) is in addition to the background dose of 0.17 mrem/yr (0.0017 mSv/yr) and the maximum dose represents 0.34 percent of the annual NESHAP limit. Appendix D provides the estimated dose at every boundary air monitor.

A collective effective dose provides an aggregate measure of the impact of airborne emissions from the Fernald Preserve to the population in the area. The collective effective dose from 2009 airborne emissions (excluding radon) to the population within 50 miles (80 km) of the Fernald Preserve was estimated to be 0.014 person-rem (0.00014 person-sievert [person-Sv]) for a population of 2.7 million. The collective effective population dose for all pathways (air and direct radiation) was estimated to be 0.042 person-rem (0.00042 person-Sv). For comparison, background radiation from the sun and naturally occurring radionuclides in the earth and food products delivered an estimated collective effective dose of 300,000 person-rem (3,000 person-Sv) to the population within 50 miles of the Fernald Preserve.

6.2 Direct Radiation Dose

Direct radiation dose to deep tissue is primarily the result of gamma and X-ray emissions from radionuclides. The largest historical source of direct radiation at the site was the waste materials stored in the silos. This and all other significant surface radiation sources were removed from the site in 2006. Remaining surface sources for radiation are soil, which contains radium, thorium, and uranium isotopes at activities that are below the FRLs established in the OU5 ROD (DOE 1996), and small pieces of debris that are exposed by soil erosion.

In past years, an estimate of direct radiation dose was calculated for the resident living nearest the boundary location with the highest measurement. This dose was estimated by using the net measurement at the location and accounting for the distance between the boundary location and the residence, which lowered the direct radiation dose because dose decreases with distance from the radiation source. The boundary fence was removed in late 2006, and direct radiation is now assessed at the monitor location, because there is no fence to prevent an individual from standing at this location. Calculation of dose at the monitor location accounts for the higher doses in 2007 through 2009, relative to dose reported in the *Fernald Preserve 2006 Site Environmental Report* (DOE 2007).

From the data in Table 5−2, the maximum measurement is 29 mrem/yr (0.29 mSv/yr) at OSL-8, and the background dose is 20 mrem/yr (0.20 mSv/yr). The difference in the OSL dose between OSL-8 dosimeter and the background dosimeter is 9 mrem/yr (0.09 mSv/yr), which is assumed to be the direct radiation dose for a hypothetical individual who stands at OSL-8 for one year. This is a very conservative estimate of the dose, as an individual would not spend an entire year at OSL-8. Additionally, Appendix C, Attachment C.2 shows that the present measurements at the boundary are indistinguishable from background results when statistical variability is considered.

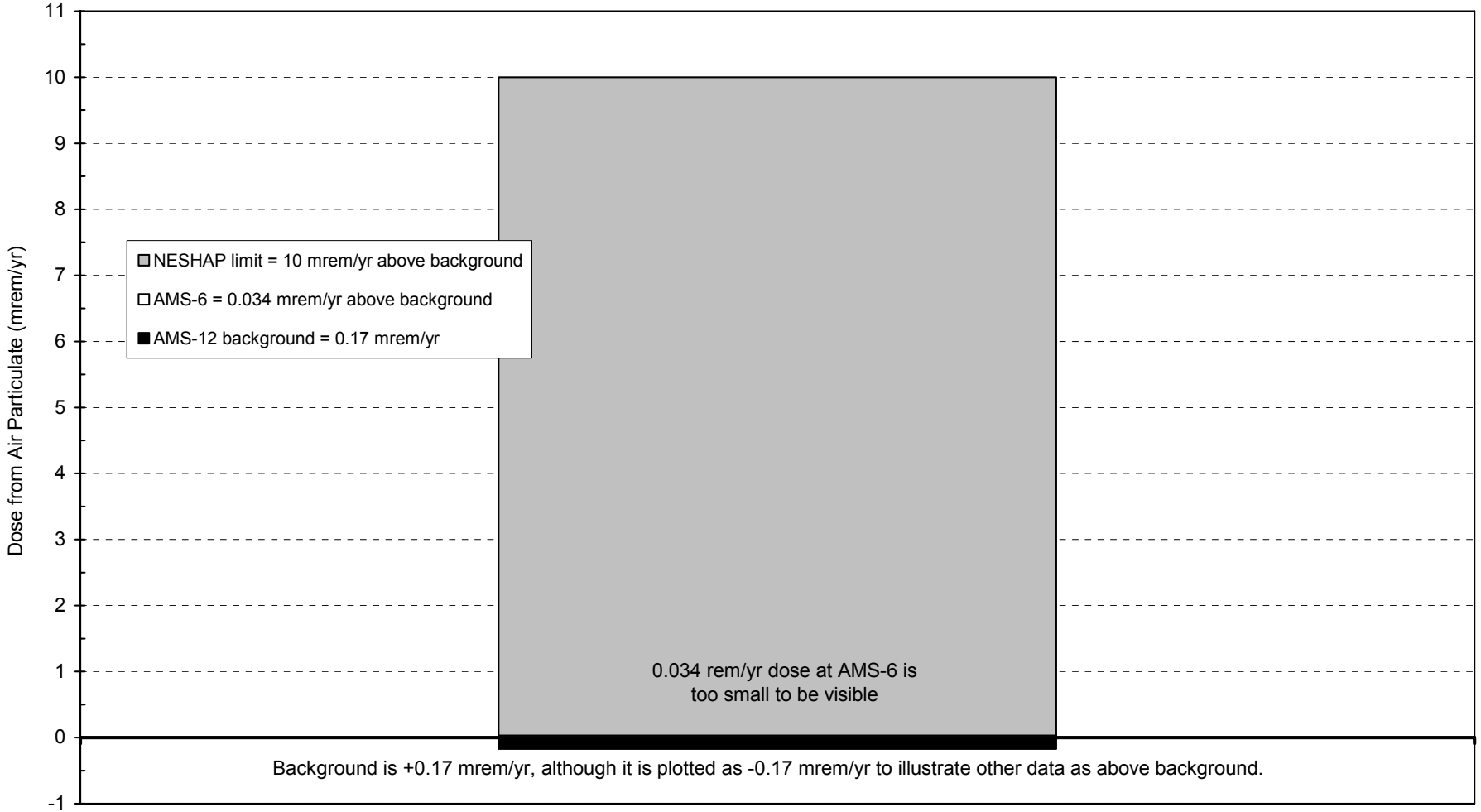

Figure 6–1. Comparison of 2009 Air-Pathway Doses and Allowable Limits

6.3 Total of Doses to the Maximally Exposed Individual

The MEI is the member of the public who receives the highest estimated effective dose based on the sum of the individual pathway doses. It is the maximum dose because the MEI is assumed to spend 24 hours a day, 365 days a year at the site boundary where maximum direct radiation and air dose are measured. As shown in Table 6−1, the 2009 dose to the MEI is 9 mrem/yr (0.09 mSv/yr) and represents the sum of the estimated doses from direct radiation and airborne emissions (excluding radon). The conservative assumptions used throughout the dose calculation process ensure that the dose to the MEI is the maximum possible dose any member of the public could receive.

Table 6–1. Dose to MEI

Pathway	Dose Attributable to the Fernald Preserve	Applicable Limit
Direct radiation at OSL-8	9 mrem/yr	100 mrem/yr (total for all pathways)
Airborne emissions at AMS-6 (excluding radon)	0.034 mrem/yr	10 mrem/yr (air pathway)
MEI[a]	9 mrem/yr	100 mrem/yr (total for all pathways)

[a]MEI is the sum of direct radiation and particulate.

The contributions to this all-pathway dose are:

- 9 mrem/yr (0.09 mSv/yr) from direct radiation to a receptor standing at OSL-8, located near the northeastern boundary of the site.
- 0.034 mrem/yr (0.00034 mSv/yr) from air inhalation dose to a receptor standing at AMS-6, located near the western boundary of the site.

The estimate represents the incremental dose above background attributable to the Fernald Preserve, exclusive of the dose received from radon. (Radon monitoring was eliminated at the end of 2008 because it was at background levels.) Figure 6−2 provides a comparison between the average background radiation dose at the background location (20 mrem/yr [0.20 mSv/yr]) and the dose to the MEI (9 mrem/yr [0.09 mSv/yr]), relative to the annual DOE limit (100 mrem/yr [1 mSv/yr]).

6.4 Significance of Estimated Radiation Doses for 2009

One method of evaluating the significance of the estimated doses is to compare them with doses received from background radiation. Background radiation delivers an annual dose of approximately 100 mrem/yr (1 mSv/yr) from natural sources, excluding radon. For example, the dose received each year from cosmic and terrestrial background radiation contributes approximately 26 mrem/yr (0.26 mSv/yr) and 28 mrem/yr (0.28 mSv/yr), respectively. This sum (54 mrem/yr) is about three times greater than the direct radiation dose of 20 mrem/yr at the background location, and it is six times greater than the 9-mrem/yr-above-background dose estimated for the individual at OSL-8. The 100 mrem/yr per person background also includes dose from the ingestion of food and medical X-rays (about 46 mrem/yr), which is not

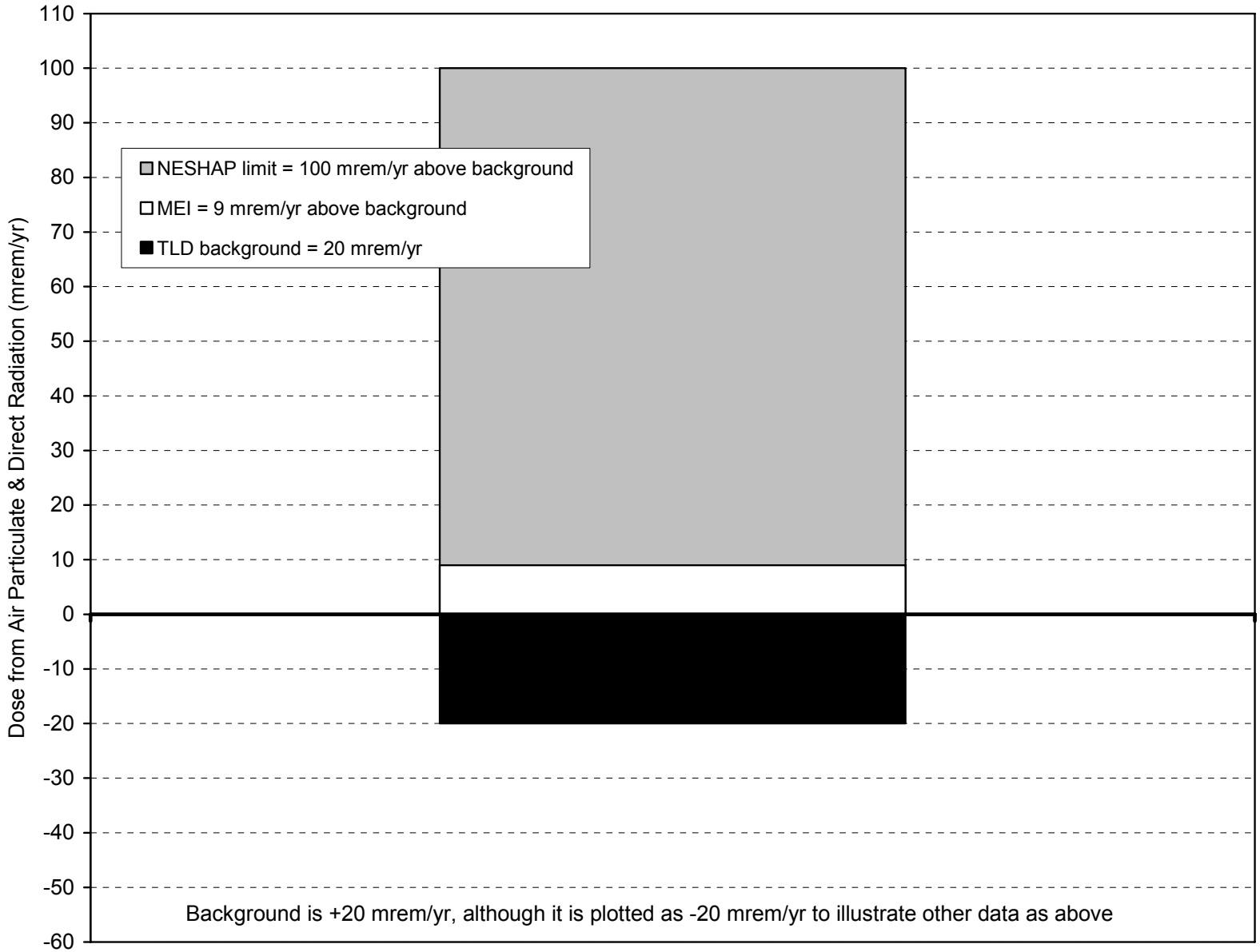

Figure 6–2. Comparison of 2009 All-Pathway Doses and Allowable Limits

recorded by the direct radiation OSLs at the boundary and background locations. In addition, the background radiation dose will vary in different parts of the country. Living in the Cincinnati, Ohio, area contributes an annual dose of approximately 110 mrem/yr (1.1 mSv/yr), whereas living in Denver, Colorado, increases the background to approximately 125 mrem/yr (1.25 mSv/yr) (NAS 1980, NCRP 1984).

Another method of determining the significance of the estimated dose is to compare it with dose limits developed to protect the public. The International Commission on Radiological Protection (ICRP) has recommended that members of the public receive less than 100 mrem/yr (1 mSv/yr) above background. As a result of this recommendation, DOE has incorporated 100 mrem/yr (1 mSv/yr) above background as the limit in DOE Order 5400.5. The sum of all estimated doses from 2009 site operations (9 mrem/yr [0.09 mSv/yr], excluding radon) is considerably below this limit (Figure 6−2).

6.5 Estimated Dose to Biota

DOE Order 5400.5 requires that populations of aquatic biota be protected at a dose limit of 1 rad/day (10 milligray per day [mGy/day]). DOE has issued a technical standard entitled *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2002b) and supporting software (RAD-BCG) for use in the evaluation and reporting of biota dose limits.

In general, the dose and compliance assessment process involves comparing radionuclide concentrations measured in surface water or sediment samples to biota concentration guides (BCGs) established by researchers. The BCGs are set so that biota exposed at the BCG level would not be expected to exceed the biota dose limit of 1 rad/day (10 mGy/day) during a calendar year. The measured radionuclide concentration in water or sediment is divided by the appropriate BCG value, and if the resulting fraction is less than 1.0, compliance with the biota dose limit is demonstrated for that nuclide. BCGs have been established for radionuclides that are relatively common constituents in past releases to the environment from DOE facilities. At facilities such as the Fernald Preserve, where multiple contaminants (e.g., radium, thorium, and uranium) can be released, a "sum-of-the-fractions" rule applies. The sum-of-the-fractions rule means each radionuclide fraction (i.e., the measured concentration divided by the BCG for that nuclide) must be summed, and the sum of all nuclide fractions must be less than 1.0.

For 2009, compliance with the dose limit to aquatic biota was determined by using the maximum concentration of each radionuclide found in Paddys Run at Willey Road (SWP-03) and effluent discharged from PF 4001 to the Great Miami River (refer to Chapter 4). The maximum concentration in water delivered from the Parshall Flume and Paddys Run is multiplied by the annual volume of water discharged from the Parshall Flume and Paddys Run to obtain a net mass for each nuclide delivered to the Great Miami River. The net mass is divided by the sum of the discharge volumes and low-flow volume from the Great Miami River to derive input concentrations to the RAD-BCG computer model. The results of this assessment indicate that the sum of the fractions for radium, technetium, thorium, and uranium isotopes is 0.005, which is well below the compliance threshold value of 1.0. Appendix C, Attachment C.4 provides additional information on the biota dose assessment.