4. Air Monitoring and Dose Assessment

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Lawrence Livermore National Laboratory performs continuous air sampling to evaluate its compliance with local, state, and federal laws and regulations and to ensure that human health and the environment are protected. Federal environmental air quality laws and U.S. DOE regulations include 40 CFR 61, Subpart H—the NESHAPs section of the Clean Air Act; applicable portions of DOE Order 458.1; and ANSI standards. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. DOE 1991) provides the guidance for implementing DOE Order 458.1.

The EPA Region 9 has enforcement authority for LLNL compliance with radiological air emission regulations. Enforcement authority for the Clean Air Act regulations pertaining to nonradiological air emissions belongs to two local air districts: the BAAQMD and the SJVAPCD.

4.1 Air Effluent Monitoring

Air effluent monitoring of atmospheric discharge points is in place for compliance with 40 CFR 61, Subpart H and is used to determine the actual radionuclide releases from individual facilities during routine and nonroutine operations and to confirm the operation of facility emission control systems. Subpart H requires continuous monitoring of facility radiological air effluents if the potential off-site (fence-line) dose equivalent is greater than 1 μSv/y (0.1 mrem/y), as calculated using the U.S. EPA-mandated air dispersion dose model, CAP88-PC, without credit for emission control devices. The results of monitoring air discharge points provide the actual emission source information for modeling, which is used to ensure that the NESHAPs standard of 100 μSv/y (10 mrem/y) total site effective-dose equivalent from the airborne pathway is not exceeded. See Appendix D for the *LLNL 2013 NESHAPs Annual Report* (Wilson et al. 2014).

The air effluent sampling program measures only radiological emissions. For LLNL operations with nonradiological discharges, LLNL obtains permits and registrations from local air districts (i.e., BAAQMD and SJVAPCD) for stationary emission sources and from CARB for portable emission sources such as diesel air compressors and generators and for off-road diesel vehicles. Current permits and registrations do not require monitoring of air effluent but do require monitoring of equipment inventory, equipment usage, material usage, and/or record keeping during operations. Based on air toxics emissions inventory and risk assessment required by the California Air Toxics "Hot Spots" Information and Assessment Act of 1987, BAAQMD and SJVAPCD have ranked LLNL as a low-risk facility for nonradiological air emissions.

4.1.1 Air Effluent Radiological Monitoring Results

In 2013, LLNL measured releases of radioactivity from air exhausts at six facilities at the Livermore Site and at one facility at Site 300. Air effluent monitoring locations at the Livermore Site and Site 300 are shown in **Figures 4-1** and **4-2**, respectively.

Three facilities had measureable emissions in 2013. A total of 1857 GBq (50.2 Ci) of measured tritium was released from the stack exhausts at the Tritium Facility. Of this, approximately 75% of tritium was released as vapor (HTO). The remaining 25% released was gaseous tritium (HT).

The National Ignition Facility (NIF) released a total of 47.7 GBq (1.29 Ci) of tritium from the stack exhaust in 2013. Of this, approximately, 78% of tritium was released as vapor (HTO). The remaining 22% was released as gaseous tritium (HT).

The Contained Firing Facility (CFF) at Site 300 had measured depleted uranium stack emissions in 2013. A total of 8.1×10^{-7} GBq (2.2×10^{-8} Ci) of uranium-234, 7.4×10^{-8} GBq (2.0×10^{-9} Ci) of uranium-235, and 6.3×10^{-6} GBq (1.7×10^{-7} Ci) of uranium-238 was released in particulate form.

The measured emissions from monitored facilities were a result of planned activities with radioactive material.

One unplanned air effluent release occurred at the Livermore Site in 2013:

On September 13, 2013, tritium was inadvertently released in Building 298. An experiment involving deuterium-tritium (DT) in an experimental container was not proceeding as expected. During the process of trying to identify the source of excess heat in an assembly, a valve was opened that caused an unexpectedly high pressure reading on a vacuum gauge. The valve was closed; however, DT gas from the experiment was emitted. The estimated amount of DT gas released was 4.0 GBq (0.109 Ci), which was 0.11% of the U.S. EPA Reportable Quantities (40 CFR 302).

CAP88-PC version 4.0.0.570 was used to model the DT source term. The MEI member of the public having highest potential dose consequence was located at 264 meters north-northeast relative to Building 298. The modeled dose was 0.00058 μSv (0.000058 mrem). This dose is well below the NESHAPs 100 μSv/y (10 mrem/y) site-wide standard dose to public.

None of the other facilities monitored for radionuclides had reportable emissions in 2013. The data tables in **Appendix A, Section A.1** provide summary results of all air effluent monitored facilities and include upwind locations (control stations) which are used for gross alpha and gross beta background comparison to stack effluent gross alpha and gross beta results.

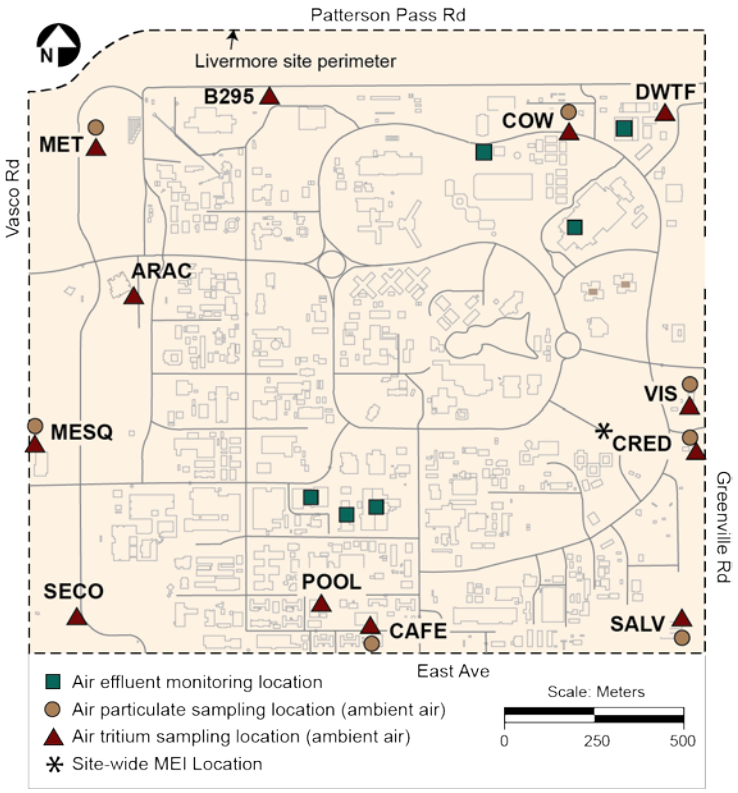

Figure 4-1. Air effluent and ambient air monitoring locations at the Livermore Site, 2013.

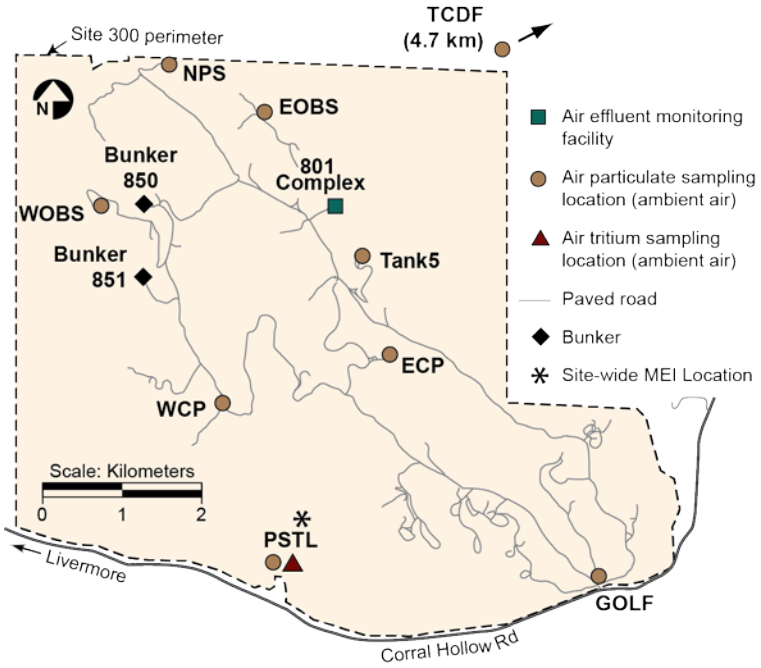

Figure 4-2. Air effluent and ambient air monitoring locations at Site 300, 2013.

4.1.2 Nonradiological Air Releases and Impact on the Environment

In 2013, the Livermore Site emitted approximately 100.2 kg/d of regulated air pollutants as defined by the Clean Air Act, including nitrous oxides (NOx), sulfur oxides (SOx), particulate matter (PM 10), carbon monoxide (CO), and reactive organic gases/precursor organic compounds (ROGs/POCs) (see **Table 4-1**). The stationary emission sources that released the greatest amount of regulated pollutants at the Livermore Site were natural gas fired boilers, internal combustion engines (such as diesel generators), solvent cleaning, and surface coating operations (such as painting). Pollutant emission information was primarily derived from monthly material and equipment usage records.

Table 4-1. Nonradioactive air emissions, Livermore Site and Site 300, 2013.

	Estimated releases (kg/d)	
Pollutant	**Livermore Site**	**Site 300**
ROGs/POCs	11.3	0.26
Nitrogen oxides	42.7	2.88
Carbon monoxide	40.5	0.67
Particulates (PM-10)	4.5	0.39
Sulfur oxides	1.2	0.17
Total	100.2	4.37

(a) DCS = Derived Concentration Technical Standard = 7.8×10^6 mBq/m^3 for tritium in air.

Livermore Site air pollutant emissions were very low in 2013 compared to the daily releases of air pollutants from all sources in the entire Bay Area. For example, the average daily emission of NOx in the Bay Area was approximately 3.0×10^5 kg/d, compared to the estimated daily release from the Livermore Site of 42.7 kg/d, which is 0.014% of total Bay Area source emissions for NOx. The 2013 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was approximately 2.36×10^5 kg/d, while the daily emission estimate for 2013 from the Livermore Site was 11.3 kg/d, or 0.005% of the total Bay Area source emissions for ROGs/POCs.

Certain operations at Site 300 require permits from the SJVAPCD. The estimated daily air pollutant emissions during 2013 from operations (permitted and exempt stationary sources) at Site 300 are listed in **Table 4-1**. The stationary emission sources that release the greatest amounts of regulated air pollutants at Site 300 include internal combustion engines (such as diesel-powered generators), a gasoline-dispensing facility, and general research operations. Combustion pollutant emissions, such as NOx, CO, and ROGs/POCs, increased in 2013 primarily due to the site-wide power outage at Site 300 that occurred on October 30, 2013, and lasted for 21 hours necessitating the startup and continuous operation of all emergency standby diesel engine generators for the duration of the power outage.

4.2 Ambient Air Monitoring

LLNL conducts ambient air monitoring at on- and off-site locations to determine whether airborne radionuclides or beryllium are being released to the environs in measurable quantities by LLNL

operations. Ambient air monitoring also serves to verify the air concentrations predicted by air dispersion modeling and to determine compliance with NESHAPs regulations.

Beryllium is the only nonradiological emission from LLNL that is monitored in ambient air. LLNL requested and was granted a waiver by the BAAQMD for source-specific monitoring and record keeping for beryllium operations, provided that LLNL can demonstrate that monthly average beryllium concentrations in air are well below regulatory limits of 10,000 pg/m^3. LLNL meets this requirement by sampling for beryllium at perimeter locations.

Based on air-dispersion modeling using site-specific meteorological data, the ambient air samplers, particularly those on the site perimeters, have been placed to monitor locations where elevated air concentrations due to LLNL operations may occur. Sampling locations for each monitoring network are shown in **Figures 4-1**, **4-2**, and **4-3**.

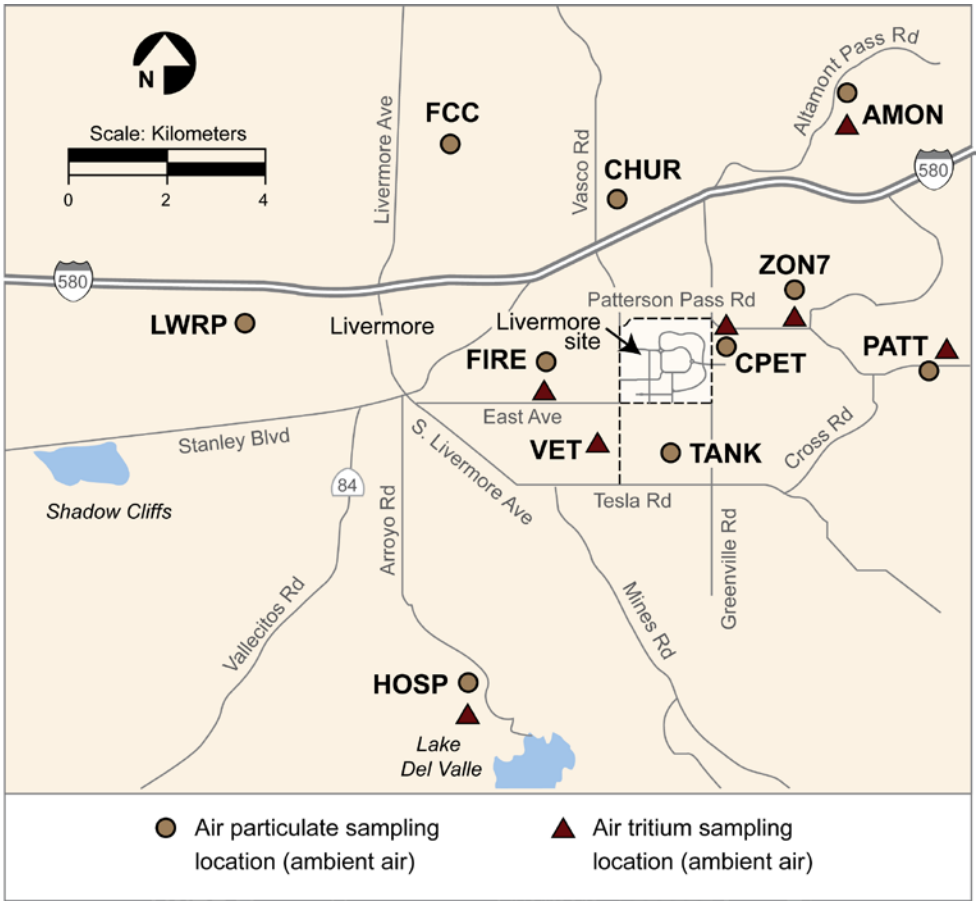

Figure 4-3. Air particulate and tritium monitoring locations in the Livermore Valley, 2013.

4.2.1 Ambient Air Radioactive Particulates

Composite samples for the Livermore Site and Site 300 were analyzed by gamma spectroscopy for an environmental suite of gamma-emitting radionuclide concentrations in air that include fission products, activation products, actinides, and naturally occurring products. The isotopes detected at

both sites in 2013 were beryllium-7 (cosmogenic), lead-210, radium-226, and potassium-40, all of which are naturally occurring in the environment.

Composite samples were analyzed by alpha spectroscopy for plutonium-239+240, which was detected in 4 out of 214 samples taken in 2013. Detections at the Livermore Site and Livermore off-site locations for plutonium-239+240 are attributed to resuspension of plutonium-contaminated soil (see Chapter 6) to ambient air from historical operations, or from resuspended fallout.

The derived concentration technical standard (DCS), which complements DOE Order 458.1, specifies the concentrations of a radionuclide that can be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public, which is 1 mSv/y (100 mrem/y) effective dose equivalent.

The Derived Concentration Standards were formerly published in DOE Order 5400.5 in 1993. The current radiation protection standards approach, which has changed from the previously adopted 1993 guidance, uses age and gender specific attributes for the population subgroups of members of the public subject to exposure incorporating more sophisticated biokinetic and dosimetric information from the International Commission on Radiological Protection (ICRP).

The highest values and percentage of the DCS for the plutonium-239+240 detections were as follows:

- Livermore Site perimeter: There were no detections in 2013.
- Livermore off-site locations: 9.8 nBq/m^3 (0.26 aCi/m^3), 0.00011 % of the DCS
- Site 300 composite: 15.3 nBq/m^3 (0.41 aCi/m^3), 0.00017% of the DCS.

Uranium-235 and uranium-238 were detected at all sample locations. Uranium ratios are used to determine the type of uranium present in the environment. Natural uranium has a mathematical uranium-235/uranium-238 ratio of 0.00725, and depleted uranium has a uranium-235/uranium-238 ratio of 0.002. The annual median uranium-235/uranium-238 isotopic ratios for 2013 were as follows:

- Livermore Site perimeter composite: 0.00726
- Site 300 sample locations: 0.00719
- Site 300 off-site location: 0.00727

The annual uranium-235/uranium-238 isotopic ratio medians are consistent with naturally occurring uranium. All of the individual uranium-235 and uranium-238 results were less than one tenth of one percent of the DCS as shown in **Appendix A**, **Section A.2**.

Gross alpha and gross beta were sampled for at all locations. The primary sources of alpha and beta activities are naturally occurring radioisotopes. Routine isotopic gamma results indicate the activities are the result of naturally occurring isotopes (uranium, radium, and lead), which are also routinely found in local soils. See **Appendix A, Section A.2**.

4.2.2 Ambient Air Tritium Concentrations

The biweekly air tritium data that are provided in **Appendix A**, **Section A.2** are summarized in **Table 4.2**. Area (diffuse) sources include stored containers of tritium waste or tritium-contaminated equipment from which HTO diffuses into the atmosphere. LLNL does not directly measure diffuse emissions. The approach used to characterize these emission sources is stated in the *LLNL NESHAPs 2013 Annual Report* (Wilson et al. 2014); a copy of this report is in **Appendix D**.

Table 4-2. Air tritium sampling summary for 2013.

Sampling locations	Detection frequency	Concentration (mBq/m^3) Mean	Median	IQR	Maximum	Median as % of DCS	Mean Dose (nSv)
Livermore Site perimeter	235 of 299	44.5	38.1	31.0	570	0.00049	10.2
Livermore Valley	71 of 171	15.8	10.2	21.3	125	0.00013	<5
Site 300	5 of 25	3.51	4.59	12.0	27.4	0.000059	<5

(a) DCS = Derived Concentration Technical Standard = 7.8×10^6 mBq/m^3 for tritium in air.

For a location at which the mean concentration is at or below the MDC, inhalation dose from tritium is assumed to be less than 5 nSv/y (0.5 µrem/y) (i.e., the annual dose from inhaling air with a concentration at the MDC of about 25 mBq/m^3 [0.675 pCi/m^3]).

4.2.3 Ambient Air Beryllium Concentrations and Impact on the Environment

LLNL measures the monthly concentrations of airborne beryllium at the Livermore Site, Site 300, and at the off-site sampler northeast of Site 300. The highest value recorded at the Livermore Site perimeter in 2013 for airborne beryllium was 17 pg/m^3. This value is only 0.17% of the BAAQMD ambient concentration limit for beryllium (10,000 pg/m^3). There is no regulatory requirement to monitor beryllium in San Joaquin County; however, LLNL analyzes samples from three Site 300 perimeter locations as a best management practice. The highest value recorded at the Site 300 perimeter in 2013 was 15 pg/m^3 and the highest value at the off-site location was 25 pg/m^3. These data are similar to data collected from previous years.

Beryllium is naturally occurring and has a soil concentration of approximately 1 part per million. The sampled results are believed to be from naturally occurring beryllium that was resuspended from the soil and collected by the samplers. Even if the concentrations of beryllium detected were from LLNL activities, the amount is still less than one percent of the BAAQMD ambient air concentration limit.

4.3 Radiological Air Dose Assessment

Dose is assessed for two types of receptors. First is the dose to the site-wide maximally exposed individual (SW-MEI) member of the public. Second is the collective or “population” dose received by people who reside within 80 km of either of the two LLNL sites.

In 2013, the SW-MEI at the Livermore Site was located at the UNCLE Credit Union, about 10 m outside the site's controlled eastern perimeter. The SW-MEI at Site 300 was located on the site's south-central perimeter, which borders the Carnegie State Vehicular Recreation Area. The two SW‑MEI locations are shown in **Figures 4-1 and 4-2**.

Table 4-3 shows average doses received in the United States from exposure to natural background radiation and other sources of radiation.

Table 4-3. Radiation doses from background (natural and man-made) and other sources of radiation.

Sources [a] (background)	Category	Individual dose (μSv) [b]	Collective dose [c] (person-Sv) [d]
	Natural radioactivity [e,f]		
	Cosmic radiation	300	2,330
	Terrestrial radiation	300	2,330
	Internal (food and water consumption)	400	3,110
	Radon	2,000	15,500
	Medical radiation (diagnostic procedures) [f]	530	4,120
	Weapons test fallout [f]	10	78
	Nuclear fuel cycle	4	31

(a) From National Council on Radiation Protection and Measurements (NCRP 1987a,b).

(b) 1 μSv = 0.1 mrem.

(c) The collective dose is the combined dose for all individuals residing within an 80-km radius of LLNL (approximately 7.77 million people for the Livermore Site and 7.11 million for Site 300), calculated with respect to distance and direction from each site. The Livermore Site population estimate of 7.77 million people was used to calculate the collective doses for "sources."

(d) 1 person-Sv = 100 person-rem.

(e) These values vary with location.

(f) This dose is an average over the U.S. population.

The annual radiological doses from all air emissions at the Livermore Site and Site 300 in 2013 were found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs 10 mrem/y site-wide standard. Using an EPA-mandated computer model and actual LLNL meteorology appropriate to the two sites, the doses to the LLNL SW-MEI members of the public from LLNL operations in 2013 were:

- Livermore Site: 1.8×10^{-2} μSv (1.8×10^{-3} mrem)
- Site 300: 4.0×10^{-7} μSv (4.0×10^{-8} mrem)

The collective EDE attributable to LLNL airborne emissions in 2013 was calculated to be 0.0018 person-Sv (0.18 person-rem) for the Livermore Site and 6.0×10^{-8} person-Sv (6.0×10^{-6} person-rem) for Site 300. These doses include potentially exposed populations of 7.77 million

people for the Livermore Site and 7.11 million people for Site 300 living within 80 km of the site centers.

The doses to the SW-MEI, which represent the maximum doses that could be received by members of the public, resulting from Livermore Site and Site 300 operations in 2013 were less than 1% of the NESHAPS 100 μSv/y (10 mrem/y) site-wide standard.

LLNL operations involving radioactive materials had minimal impact on ambient air during 2013. The measured radionuclide particulate and tritium concentrations in ambient air at the Livermore Site and Site 300 were all less than one percent of the DOE primary radiation protection standard for the public (DCS). The SW-MEI doses from both sites for 2013 in comparison to the dose from radon shown in **table 4-3**, is less than one-tenth of one percent to naturally occurring radiation.

See the *LLNL NESHAPs 2013 Annual Report* (Wilson et al. 2014) for a complete description of dose (individual and collective), air dispersion modeling, and air monitoring; the NESHAPs report is located in **Appendix D**.

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