4. Air Monitoring Programs

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Lawrence Livermore National Laboratory (LLNL) 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. Department of Energy (DOE) regulations include 40 CFR 61, Subpart H—the National Emission Standards for Hazardous Air Pollutants (NESHAPs) section of the Clean Air Act; applicable portions of DOE Order 458.1; and American National Standards Institute (ANSI) standards (N13.1-1969, 1999 [reaffirmed 2011]. The *Environmental Radiological Effluent Monitoring and Environmental Surveillance* (DOE 2015) handbook provides the guidance for implementing DOE Order 458.1.

The U.S. Environmental Protection Agency (EPA) Region IX 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 Bay Area Air Quality Management District (BAAQMD) and the San Joaquin Valley Air Pollution Control District (SJVAPCD).

4.1 Air Effluent Monitoring

Air effluent monitoring of atmospheric discharge points is in place for compliance with 40 CFR Part 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 2017 NESHAPs Annual Report* (Wilson et al. 2018).

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 the California Air Resources Board (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 2017, LLNL measured releases of radioactivity from air exhausts at five 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 measurable emissions in 2017. A total of 1621 GBq (43.8 Ci) of measured tritium was released from the stack exhausts at the Tritium Facility. Of this, approximately 85% of tritium was released as vapor (HTO). The remaining 15% released was gaseous tritium (HT).

The National Ignition Facility (NIF) released a total of 42.6 GBq (1.15 Ci) of tritium from the stack exhaust in 2017. Of this, approximately, 82% of tritium was released as HTO. The remaining 18% was released as HT. Note: The glycol bubbler that collects tritium from the NIF stack was sent back to the vendor for repair in November 2017 due to a faulty heat controller. The bubbler sampled tritium as HT for a total of 206 days in calendar year (CY) 2017; the bubbler sampled HTO for a total of 323 days in CY2017.

A Monte Carlo was developed to estimate the amount of HT and HTO for all non-monitored days. The estimate was based on 10,000 iterations each for HT and HTO. The highest value was used as a conservative approach in comparison to the straight mean (apply the average of measured emissions as estimate). The HT estimate, as an example, had a straight mean of 83 mCi. The mean of all Monte Carlo runs was also 83 mCi as expected. The highest Monte Carlo value was 94 mCi and is used as the estimate for HT.

The glycol bubbler was received repaired from the vendor in early CY2018, and is online continuously monitoring tritium from the NIF stack.

The Contained Firing Facility (CFF) at Site 300 had measured depleted uranium stack emissions in 2017. A total of 1.2×10^{-5} GBq (3.3×10^{-7} Ci) of uranium-234, 8.5×10^{-7} GBq (2.3×10^{-8} Ci) of uranium-235, and 8.5×10^{-5} GBq (2.3×10^{-6} Ci) of uranium-238 was released in particulate form.

None of the other facilities monitored for radionuclides had reportable emissions in 2017. 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.

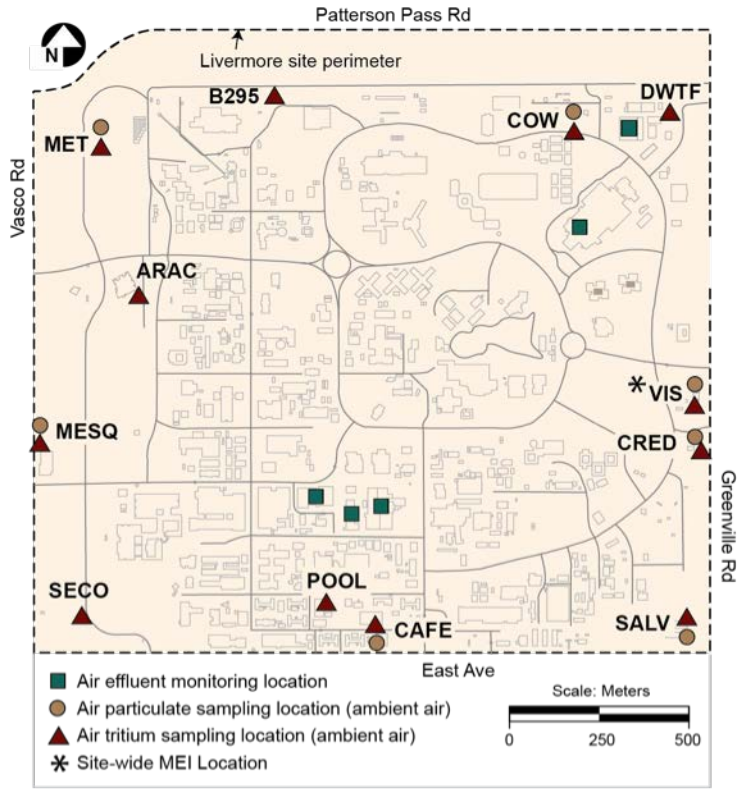

Figure 4-1. Air effluent and ambient air monitoring locations at the Livermore Site, 2017.

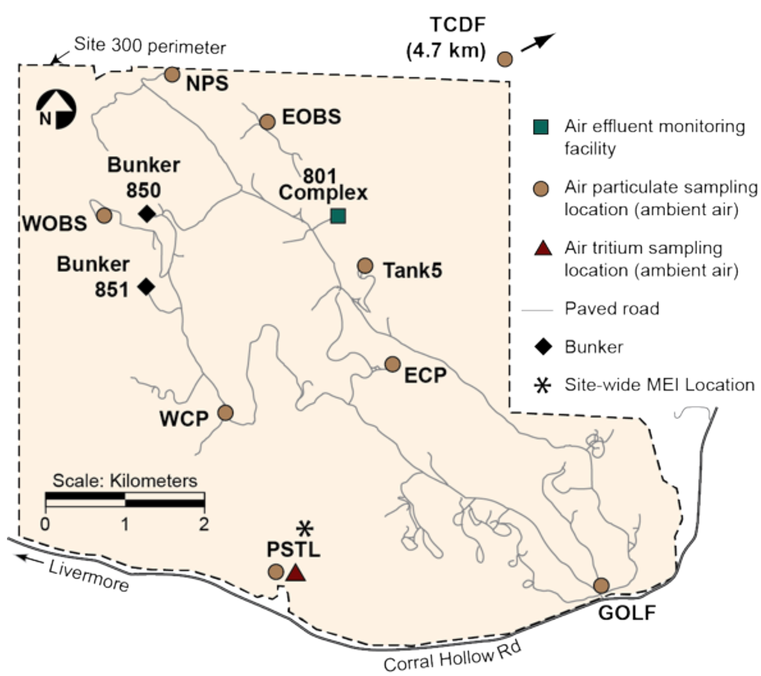

Figure 4-2. Air effluent and ambient air monitoring locations at Site 300, 2017.

4.1.2 Nonradiological Air Releases and Impact on the Environment

In 2017, 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 (PM10), 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, 2017.

	Estimated releases (kg/d)	
Pollutant	**Livermore Site**	**Site 300**
ROGs/POCs	13.5	0.30
Nitrogen oxides	37.4	3.17
Carbon monoxide	42.7	0.73
Particulates (PM10)	4.7	0.41
Sulfur oxides	1.9	0.19
Total	100.2	4.8

Livermore Site air pollutant emissions were very low in 2017 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 is estimated to be 2.3×10^5 kg/d, compared to the estimated daily release from the Livermore Site of 37.4 kg/d, which is 0.016% of total Bay Area source emissions for NOx. The 2017 BAAQMD estimate for ROGs/POCs daily emissions throughout the Bay Area was approximately 2.2×10^5 kg/d, while the daily emission estimate for 2017 from the Livermore Site was 13.5 kg/d, or 0.0061% 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 2017 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, including NOx, CO, PM10, SOx, and ROGs/POCs increased in 2017 primarily due to three site-wide electrical power outages totaling 12.7 hours.

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**.

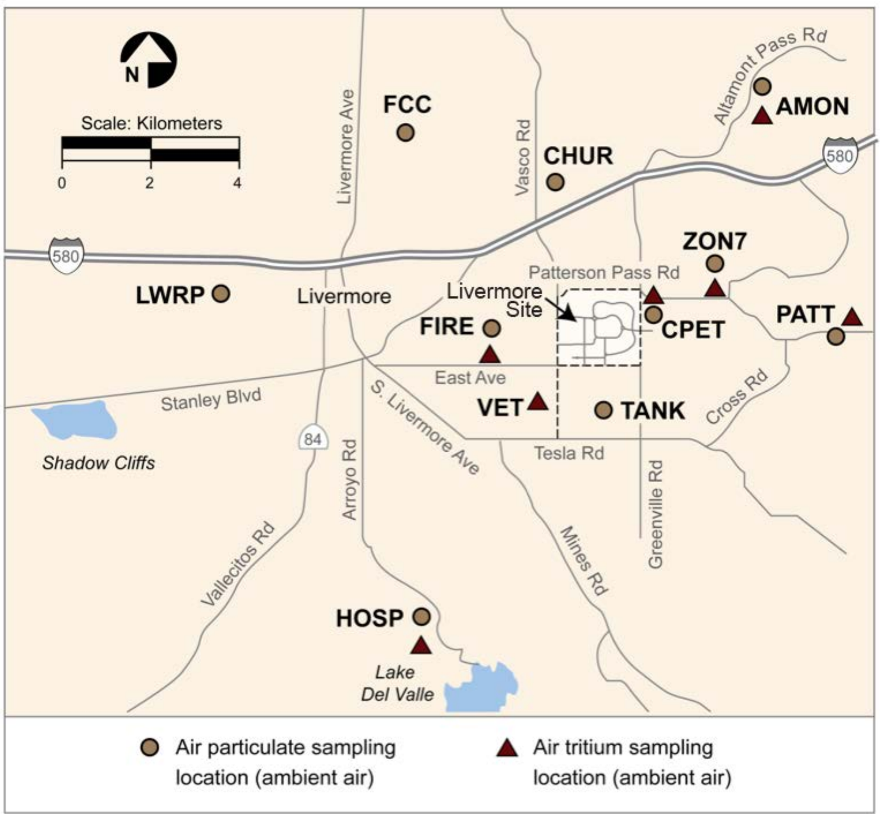

Figure 4-3. Air particulate and tritium monitoring locations in the Livermore Valley, 2017.

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 isotopes. The isotopes detected at both sites in 2017 were beryllium-7 (cosmogenic), lead-210, 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 7 out of 216 samples taken in 2017. Detections at the Livermore Site, Site 300, and

Livermore off-site locations for plutonium-239+240 are attributed to a number of factors that include: resuspension of plutonium-contaminated site (see **Chapter 6**), resuspended fallout from previous atmospheric testing, or resuspended fallout from the Fukushima nuclear accident.

The derived concentration 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 DCS was formerly published in DOE Order 5400.5 (Radiation Protection of the Public and the Environment) 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: 13.4 nBq/m^3 (0.36 aCi/m^3), 0.00015% of the DCS.
- Livermore off-site locations: 10.7 nBq/m^3 (0.29 aCi/m^3), 0.00012 % of the DCS.
- Site 300 composite: 6.84 nBq/m^3 (0.18 aCi/m^3), 0.000076% of the DCS.

Uranium-235 and uranium-238 were detected at all sample locations. Uranium ratios, which can be calculated by mass or by atom, 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 typical uranium-235/uranium-238 ratio of 0.002. The annual median uranium-235/uranium-238 isotopic ratios for 2017 at the Livermore Site and off-site location were:

- Livermore Site perimeter composite: 0.00724.
- Off-site TCDF (located 4.7 km northeast from Site 300): 0.00723.

The annual uranium-235/uranium-238 isotopic ratio medians are consistent with naturally occurring uranium.

Site 300 has not had atmospheric depleted uranium shots since September 2007. However, there are still areas of depleted uranium contaminated soil. Wind-driven resuspension as well as soil disturbance from construction-type activities and fire road maintenance showed a depleted uranium signature in one sample at the location of the site-wide maximally exposed individual (SW-MEI) (see **Figure 4-2**). The uranium-235 to uranium-238 isotopic ratio was 0.0066; this results in approximately 14% depleted uranium with the other 86% of the uranium naturally occurring.

All of the individual uranium-235 and uranium-238 results, including samples showing a depleted uranium signature, were less than one tenth of one percent of the DCS as shown in **Appendix A**, **Section A.2**.

All locations were sampled for gross alpha and gross beta. 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

LLNL emits tritium to the air from multiple sources. These sources include monitored stack sources, such as the Tritium Facility and NIF, unmonitored stack sources having minor emissions of tritium, and area sources. 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, but estimates the radiation dose to the public from these sources given measurements taken using the ambient air tritium sampling network. The ambient air tritium sampling network measures HTO concentrations in the air from all sources. This information, along with measured stack emissions, is used to provide an estimate of the dose to the public from diffuse area tritium emissions. The approach used to characterize the area emission sources is stated in the *LLNL NESHAPs 2017 Annual Report* (Wilson et al. 2018). See **Appendix D** for a copy of this report. The biweekly air tritium data that are provided in **Appendix A**, **Section A.2** are summarized in **Table 4-2**.

Table 4-2. Ambient air tritium sampling summary for 2017.

Sampling location	Detection frequency[(a)]	Concentration (mBq/m^3)				Median as % of DCS	Mean dose[(b)](nSv)
		Mean	Median	IQR	Maximum		
Livermore Site perimeter	282 of 309	55.3	37.4	40.5	518	0.00048	13.0
Livermore Valley	122 of 177	26.9	15.3	18.4	414	0.00020	6.31
Site 300	11 of 26	7.93	8.38	8.91	23.9	0.00011	<5

(a) Detection frequency indicates the number of samples that measure less than 100% of 2-Sigma uncertainty (see Chapter 8).

(b) Based on an annual breathing rate of 8103 m^3 and inhalation dose conversion factor of 1.93×10^{-11} Sv/Bq (DOE-STD-1196-2011). Dose due to HTO absorption through skin is accounted for. It is estimated as equaling one-half of the dose due to inhalation (2001 Environmental Report, Appendix A).

(c) Median as a percent of DCS is not used when the median is a negative value (see Chapter 8)

For a location at which the mean concentration is at or below the minimal detectable concentration, dose from tritium is assumed to be less than 5 nSv/y (0.5 µrem/y).

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 2017 for airborne beryllium was 21 pg/m^3. This value is 0.21% 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 2017 was 31 pg/m^3 and the highest value at the off-site location was 20 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 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 2017, the SW-MEI at the Livermore Site was located at the Country Pet Hospital, about 35 m outside the site’s 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 sources of radiation.

Table 4-3. Radiation doses from ubiquitous background and man-made sources of radiation.

Source category [a]	Individual dose (μSv) [b, c]	Collective dose [d] (person-Sv) [e]
Natural radioactivity [f]		
Cosmic radiation	330	2,570
Terrestrial radiation	210	1,640
Internal (food and water consumption)	290	2,260
Radon and Thoron	2,280	17,800
Medical radiation procedures	3,000	23,400
Consumer	130	1,010
Industrial plus occupational	8	62

(a) From National Council on Radiation Protection and Measurements, Report No. 160, Table 8.1 (NCRP 2009).

(b) 1 μSv = 0.1 mrem.

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

(d) The collective dose is the combined dose for all individuals residing within an 80-km radius of LLNL (approximately 7.8 million people for the Livermore Site and 7.1 million for Site 300), calculated with respect to distance and direction from each site. The Livermore Site population estimate of 7.8 million people was used to calculate the collective doses for the source categories.

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

(f) These values vary with location.

The annual radiological doses from all air emissions at the Livermore Site and Site 300 in 2017 were found to be well below the applicable standards for radiation protection of the public, in particular the NESHAPs 100 μSv/y (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 2017 were:

- Livermore Site: 1.9×10^{-2} μSv (1.9×10^{-3} mrem).
- Site 300: 4.8×10^{-4} μSv (4.8×10^{-5} mrem).

The collective effective dose equivalent (EDE) attributable to LLNL airborne emissions in 2017 was calculated to be 0.0013 person-Sv (0.13 person-rem) for the Livermore Site and 7.2×10^{-7} person-Sv (7.2×10^{-5} person-rem) for Site 300. These doses include potentially exposed populations of 7.8 million people for the Livermore Site and 7.1 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 where there is a residence, school, business, or office, resulting from Livermore Site and Site 300 operations in 2017, were less than one percent of the NESHAPS 100 μSv/y (10 mrem/y) site-wide standard.

LLNL operations involving radioactive materials had minimal impact on ambient air during 2017. 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 2017 in comparison to the dose from radon shown in **Table 4-3** are much less than one-tenth of one percent of naturally occurring radiation.

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